Perspectives on Robots

A reality check on imagined futures

REELER

Responsible
Ethical Learning
with Robotics

Perspectives on Robots

A reality check on imagined futures

An interdisciplinary publication written together by REELER researchers from the fields of anthropology, economics, engineering, sociology and philosophy.

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Preface and Acknowledgments

The REELER project runs from January 2017 to January 2020 and is filled with collaborative learning across disciplinary borders, among people who came with different motives, wanted different things from the project, saw it grow, disintegrate, and grow again and gradually aligned. During this period, more than 40 researchers (many of whom were young student helpers and translators) from all over Europe have participated in the research. The REELER consortium, consisting of the four partners Cathrine Hasse, Maria Bulgheroni, Andreas Pyka, and Kathleen Richardson, would like to thank them all. Not least, our hardworking researchers (in no particular order), Karolina Zawieska, Ben Vermeulen, Maja Hojer Bruun, Niels Christian Mossfeldt Nickelsen, Jamie Wallace, Louise Bøttcher, Mia Mathiasen, Christina Leeson, Donovan Anderson, Kane Carreras-Gogh, Kate Davis, Valentina Simonetti, Alex Gimondi, Walter Baccinelli, Alejandra Gomez, Sara-Lynn Lepage, Sophie Urmetzer, Lila Anne Todd, Christian Djerving, Stephan Hansen, Wienke Reimer, Jessica Sorenson and Sebastian Madsen. Without their work this project would not have been possible.

Our engaged advisory board members have given insightful advices: Christina Cristalli, Anne Edwards, Charles Ess, Vincent Müller, Sabine Pfeiffer, Paolo Saviotti, Johanna Seibt, and Marilyn Strathern.

We also thank the European Commission and the Horizon 2020 Research and Innovation programme who took a chance permitting a project on robots to be based on ethnographic studies and a basic anthropological approach – but also for ensuring that our work could become truly interdisciplinary.

The many robot developers, policymakers, and affected stakeholders who let us follow their work for longer or shorter periods cannot be thanked in person for reasons of 'non-disclosure', but if you read this please accept our gratitude. That you let us into your lives, even for a short period of time, provided REELER with such a rich basis for analysis and conclusions.

The results presented are our responsibility and we can only hope we through REELER have opened the door to many more interdisciplinary studies of this kind. They are needed.

The REELER consortium
01.10.2019

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PART ONE
Introducing the inner circle of robotics

In Part One, we describe the Human Proximity Model, which REELER has developed over the course of our research, and which has served as a guiding framework for our analysis. We unfold our research on how robot makers collaborate in what we term the inner circle, and on robot developers' motivations for designing robots. In the inner circle, we find robot developers in close collaboration with robot facilitators and application experts. Though end-users are spoken for by spokespersons, they are rarely part of the actual collaborations, except as test persons. Furthermore, we find that other types of affected stakeholders are generally overlooked – perspectives we elaborate on in Part Two and Part Three.

Chapter 1

Introduction

Interviewer: Has the interview changed any perceptions that you have about humans?

Bill: It's actually made me appreciate what kind of complex things we are, and to try and emulate that with a robot just goes to show how complex we are – the fact that we can do, think, create, all within a flexible thing, really.

(Bill, vehicle mechanic, affected stakeholder, HERBIE)

◀ (Photo by Kate Davis)

1.0 Introduction

Technology has never been more invasive and disruptive than in present day Europe. Robotization, coupled with artificial intelligence, is transforming homes, public institutions like schools and hospitals, as well as workplaces, at a pace that can only be described as accelerating. In some ways it seems we live in a techno-paradigm, in an era of a new 'great history' of how technology can solve all problems presently and in the future. Many developers and policymakers see this development as promising, but they also acknowledge the need for closer contact with the general public and societal concerns. At the same time, many people affected by technological transformation find themselves unprepared and worry about the changes development brings. Media imagery of robots as intelligent and even violent humanoids may contribute to these worries enmeshed in a meta-narrative of how this development is inevitable. In this publication we try to bring together the voices of different stakeholders engaged in and/or affected by a robotic society - and to give politicians and the general public a reality check on what robots are, and what we can expect them to do.

This publication is the outcome of extensive ethnographic and economic research into robot design, development, implementation, and related ethical challenges conducted by an interdisciplinary team of researchers in the EU-project REELER (Responsible Ethical Learning in Robotics) which runs from January 2017 to January 2020. The ethnographic data consists of 11 cases selected for variation in robot types, application sectors, geographical places, and types of organizations (*see Hasse 2019*). With this multi-variation approach, REELER first sought diversity in case selection, then analyzed for patterns across cases. Each REELER case is given one case name, but can cover several robots within that sector or robot type classification.

The 11 REELER cases cover robots constructed for autonomous transport (HERBIE), logistics (WAREHOUSE), construction (WIPER), manufacturing (COOP), healthcare (REGAIN), agriculture (SANDY), inspection (OTTO), cleaning (SPECTRUS), and consumer/education (ATOM) and includes social robots (BUDDY) and collaborative robots (COBOT) applied across sectors. Our focus was not on robots already applied, but robots being developed and tested from ideas and beginnings (TRL 1) to 'ready for market' (TRL 9). However, since many robot developers build upon off-the-shelf robots when developing new robots, our research also includes some robots already on the market.

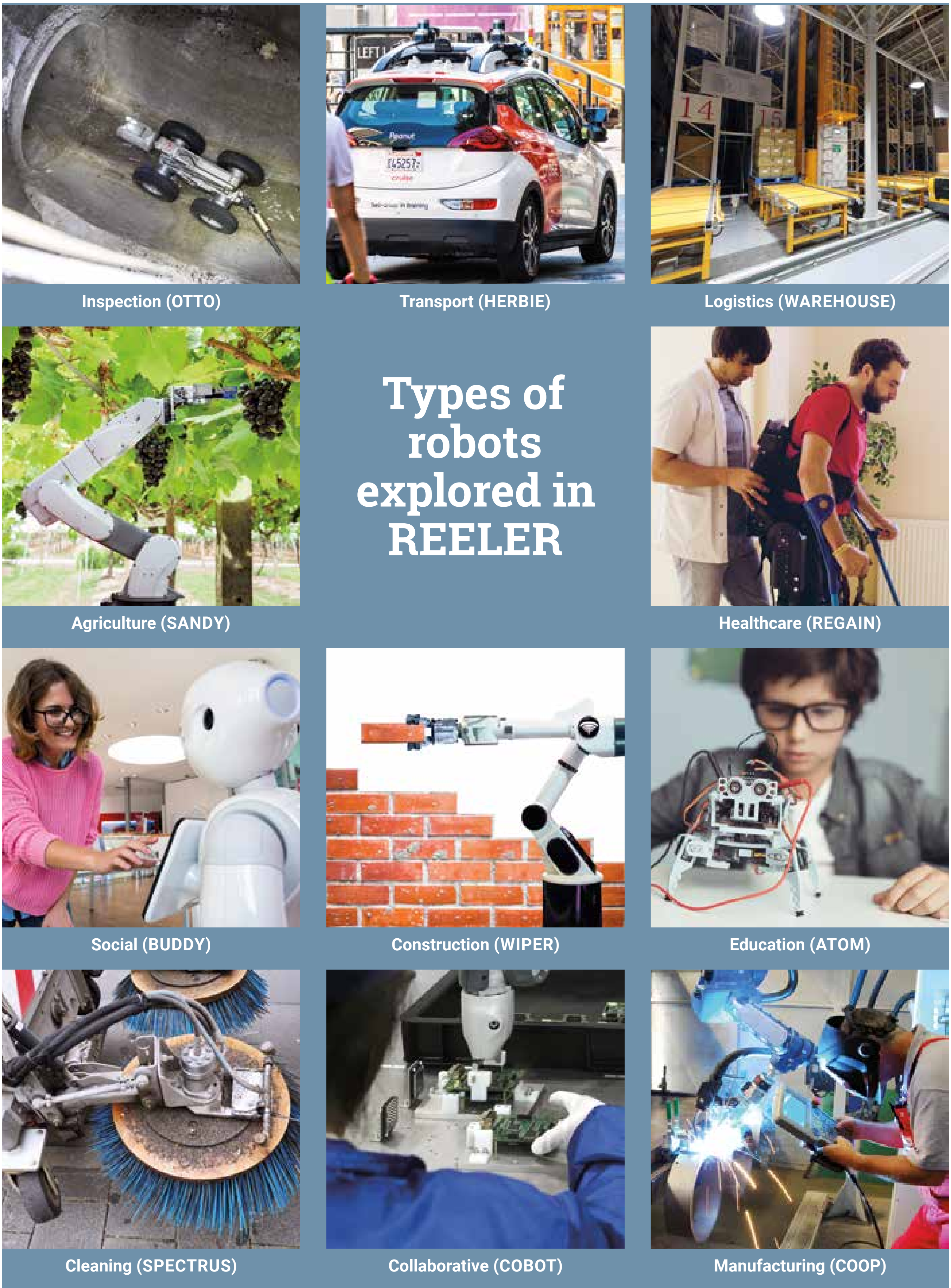


Figure 1.1. Overview of REELER case categorizations

In total, 160 in-depth ethnographic interviews with both robot developers and end-users/affected stakeholders have been conducted. These interviews and observations from the field are compiled into case write-ups and processed in qualitative data analysis software, which formed the basis of our initial analysis. Selected excerpts from these interviews and field notes are anonymized and used throughout this publication to illustrate the key arguments in each chapter.

1.1 The goal of the REELER project

The goal of the REELER project is to align robot makers' visions of a future with robots with empirically-based knowledge of human needs and societal concerns, through a new proximity-based human-machine ethics. By giving voice to those affected by robots, the project intends to close the gap between robot makers and these affected stakeholders. REELER's research brings forth data on how individuals and communities connect with robotic technologies, with special attention to the ethical, economic, and social impacts of robots. The outcome of the REELER project is the REELER Roadmap, consisting of this publication, the Human Proximity Model, research publications, a collection of tools for collaborative learning, and condensed findings for robot developers presented in our Awareness-Raising Toolbox (see responsiblerobotics.eu/toolbox).

Our tools for collaborative learning include:

- BuildBot, an interactive board game,
- BRICKSTER, a serious puzzle game,
- REELER mini-publics, a forum for knowledge transfer and debate among experts and the general public, and
- Social Drama, a method to explore our own assumptions.

The purpose of the publication *Perspectives on Robots* is to raise awareness of the issues identified in REELER's ethnographic and economic research. Through engaging closely with the people making robots *and* the people affected by robots, the REELER project identifies one central finding:

In order to ensure ethical and responsible robot design, it is essential to adopt a two-pronged strategy to: a) enhance robot developers' awareness of affected stakeholders and b) align robot makers' and affected stakeholders' motives by increasing human proximity through the involvement of alignment experts, for effective collaborative learning.

Collaborative learning is a process of alignment of different motives and expectations in working toward a common goal. This definition is inspired by Anne Edwards' work on relational agency (Edwards 2010). Robot makers engage in the *activity* of creating robots and are thus working towards a common *object* – the finalized robot. The motives for their daily *actions* lie in how the object is envisioned through a common understanding developed among the robot makers. In other words, they share an *object motive* when they collaborate: "The idea of **object motive** importantly recognizes that our actions are elicited by our interpretations of the object" (Edwards 2007, 7). In our research, motives were often not overtly stated or even acknowledged, but constitute the underlying reasons for engaging in development activities. Because the robot makers often meet each other and have similar backgrounds, their object motives are to some extent already aligned when they work towards creating new robots. Their motives to make robots stem from what is at hand in their shared cultural world (or inner circle of robotics), which includes developers, funding agencies, and application experts (*see Figure 1.2*) negotiating everyday design decisions and shaping the direction of robotics through these close collaborations.[1]

Collaborative Learning: *a process of alignment of different motives and expectations in working toward a common goal.*

Motive: *The underlying reason for engaging in activities of collaboration to achieve a common goal defined as 'an object'.*

When collaboration is expanded to the wider context of development, we see gaps in the motives of the persons working together to solve a particular problem (nursing staff shortages, for example). How the robot makers interpret the problem may differ from how nurses or hospital managers interpret the problem; *and*, their motives for collaborating may be very dissimilar. The managers may want to procure a robot to avoid recruitment costs, while the nurses may choose to be involved in the development to ensure the robot assists them without taking over their core care tasks and the patients need a robot that can help them get well. Meanwhile, a robot developer seeks to prove the application of a new breakthrough in robotics, while the company he works for aims to tap into an emerging market in healthcare robotics. Bringing these motives together in alignment with the shared goal of robot development requires increased *human proximity*, i.e. bringing the robot and robot makers closer to the needs of the various affected stakeholders. This need for alignment of motives is recurring across REELER cases irrespective of what type of robot, where the robot is produced, or the sector of application.

1.2 Human Proximity Model

In order to organize our findings of patterns analytically, as well as to talk about these findings cross-disciplinarily, we have found it necessary to develop a new vocabulary for the groups of people we have studied and their roles in development. In the following sections, we define the main terms you will meet throughout the publication. These terms are

1 More can be found on motives and collaborations in 2.0 Robot beginnings and 3.0 Collaboration in the Inner Circle.

presented through our model of human proximity, which in many cases functions as our analytical lens.

REELER has developed a *Human Proximity Model* (HPM) to illustrate how changes in collaboration practices may bring about greater human proximity, to contribute to more responsible and ethical design of robots. To start with, we have made a descriptive model of the types of collaborations observed in REELER's fieldwork. Each of REELER's ethnographic case studies begin by identifying one or more **robots** and the people responsible for their development. From there we trace out a network of collaborators that are involved in the development processes. In our exploration of these robot beginnings, we begin to see insular patterns of involvement, where persons with particular expertise take on the same roles in case after case. First, we identify **robot developers,** who use their technical expertise to actually make the robots. We also find that no robot is created by developers alone. Many robots would never have been made without funding from **facilitators**, for example. In fact, it is often facilitators who define the problem that a particular robot development intends to solve. Many of the developers we have spoken to point out that in order to adequately solve a problem in an unfamiliar field, they engage with **application experts**, whose knowledge helps them specify requirements in the design process. These three groups of people often gather at conferences, fairs, and expositions to shape the future of the robotics field. They attend EU organized events to shape policy or access funding. But most importantly, they *make* the robots happen and are thus collectively termed **robot makers**. At the center of this group are shared motives and activities around the **robot**. In the context of REELER, we define a robot as a material object consisting of adequate technical parts that facilitate sensing, processing and acting on the basis of information from the environment. Simultaneously the robot is a conceptual entity, which is subject to continuous negotiation.

Thus, the inner circle of the model, with robot makers surrounding the robot, consists of the following sub-categories:

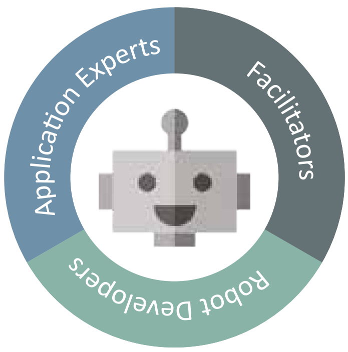


Figure 1.2. The 'inner circle' where robot developers such as engineers work together with facilitators (funding agencies, e.g.) and application experts (psychologists, e.g.).

Robot: *Simultaneously a conceptual entity and material object, affecting people in different ways.*

Robot makers: *People directly involved in robot development.*

Developers: *People with technical expertise, whose role is to develop robots in whole or in part (e.g., mechanical engineers, computer scientists, industrial designers).*

Facilitators: *Decision-makers whose role is to set the framework for development. This includes people with legal, regulatory, or bureaucratic expertise (e.g., funding bodies, regulatory agencies), but also persons who otherwise facilitate the funding, access to market, or testing (e.g., lawyers, investors, marketing, or public-relations persons).*

Application experts: *People with an expertise in the application area or sector particular to the robot under development. They have a role of sharing their expertise with developers, and are often robot buyers (e.g., a contractor or building developer for a construction robot, or a dairy owner for a milking robot).*

Despite the diversity within this group of robot makers, we see a common culture in what we call the robot makers' *inner circle*. Each of us is equipped, by our experiences, with particular tools for engaging with the world; anthropologists call it culture when people share the same tools and develop a common mindset. We find that persons in the inner circle often work from a shared set of expectations and backgrounds. The persons are most often male, and often have similar backgrounds including a higher education. Likewise, to some extent, they share a common language around robotics and have relatively aligned motives that bind them together. Robot developers are very good at collaborating in complex networks with many different actors within this inner circle of robotics.

1.2.1 Moving outside the inner circle

These engagements do, however, not necessarily entail alignment of the motives of robot developers and those we term *affected stakeholders* – among these most notably the *end-users.* To give an example from a healthcare robot, a group of robot developers invite a hospital manager to establish a business case. They invite nursing managers to help specify requirements in the beginning stages of design. During prototyping, they test the solution among patients in a real hospital setting (including the porters and nurses), and finally, they might consult with a representative of the nursing union to ensure acceptance upon implementation. All of these collaborations are integral to good design.

Yet, none of these steps involve actual *collaboration* with affected stakeholders (in this case nurses and patients) with the aim of finding out about their motives and needs. Going

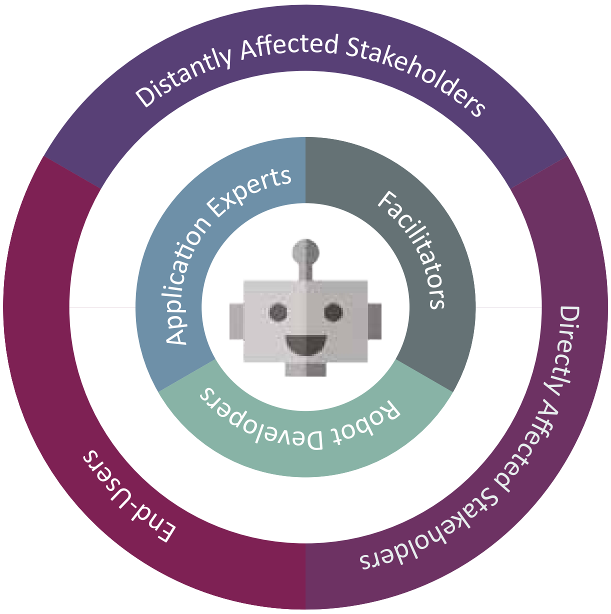


Figure 1.3. The proximity gap between robot makers (in the inner circle) and the affected stakeholders (end-users, directly- and distantly affected stakeholders).

across cases, REELER finds that **end-users** (for instance a patient training to walk with a robot) are typically simply involved as test-persons in the later stages of robot development. They are not given an independent voice in the process of development. Thus, we identify a proximity gap between robot makers and end-users, which is one of the gaps the REELER project (and this publication) aims to address.

In addition to end-users, REELER has identified two new categories of potential affected stakeholders, which are often overlooked in any types of collaborations in the inner circle. We call these two categories of people directly affected stakeholders and distantly affected stakeholders. Among the **directly affected stakeholders** we identify people close to the end-users; people who are supposed to interact with the robots without being intended users themselves. This group of directly affected stakeholders are often overlooked (in the case of the healthcare robot it could be the nurses helping the patient engage with the robot or porters bringing the robot). If this group of directly affected stakeholders are included in the development phase, it is often as test-persons, as with the end-users. Thus, their voices about how the robot affects their work or life are not heard in the design phases. This can have severe implications for the uptake of robots when the robot is brought to market.

The group of **distantly affected stakeholders** comprises people who are affected by the robots, even though they are never near the robot or never meet anyone from the inner circle. As robots come out of the industrial cage into people's everyday lives, people are increasingly distantly affected. These people have no say in the form of design and implementation. Distantly affected stakeholders might be fruit pickers, nurses, shop-floor workers, cleaning ladies, or warehouse workers who get new tasks or need re-skilling to be able to accommodate to changes in their work situation (for instance, to become end-users who collaborate directly with robots). The REELER's research also includes these distantly affected stakeholders, and their voices are heard throughout the chapters of this publication.

We refer to this group of end-users, directly and distantly affected stakeholders as **affected stakeholders.** Their motives are not represented – or considered – by the people in the inner circle because they are outside the purview of the robot developers and their direct collaborators.

Affected stakeholders: *Those who may use robots or be affected by robots, directly or distantly.*

End-users: *People who will use (operate or interact with) the robot directly (e.g., a patient using a rehabilitation robot, a machine operator at a factory, or a consumer using a robotic vacuum).*

Directly affected stakeholders: *Non-users who encounter the robot and are affected by it (e.g., a family member assisting patient with use of a rehabilitation robot, or a nurse interacting with a cleaning robot).*

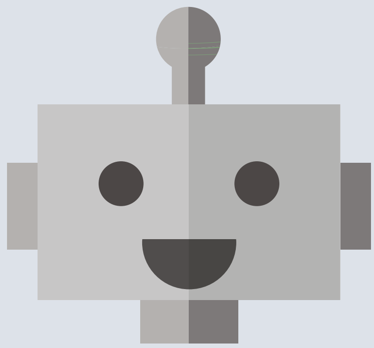
Distantly affected stakeholders: *People who will likely never operate, use, or interact directly with the robot, but may nevertheless be affected by it (e.g., a physiotherapist made superfluous, a farmworker on a traditional farm rather than a farmer working in a precision-farming setting).*

The first REELER case studies took their point of departure in a given robot. This approach showed that the robot makers were not aware of or did not experience the alignment gap we identify between robot developers and affected stakeholders. Many of them sincerely believe they cover the interests and experiences of the end-users. Nevertheless, they largely overlook directly affected stakeholders and do not see distantly affected stakeholders as part of the problem their robot is designed to solve. Moreover, it brought some surprise to the robot makers to hear about the people REELER considers 'end-users' in our research. When the robot makers spoke about end-users they referred to, for instance, people buying robots, but not people who would be operating or be in close proximity to the robot.

The following de-identified story from the field exemplifies this issue of robot developers speaking about end-users as the managers of a cleaning company, not the staff who will be operating the new cleaning robot.

STORY FROM THE FIELD:

The process of developing robots in the inner circle



Here we follow the process of developing a cleaning robot, FLOSSI, from the perspective of a group of robot developers. They draw inspiration from a technology developed in a previous project and from an existing social collaboration with people from the inner circle of robotics. They meet on a regular basis at fairs, competitions and conferences where they also listen to policymakers and hear about funding possibilities. At some point they decided to develop a new project together.

Interviewer: "But was it your idea in the beginning? It was with your Belgian colleagues?"

Vincent: "Yes, it was this partner we worked very close with on several projects. This is exactly an example of how it works because it was not one person saying this, it just came through brainstorm. So, discussing with a partner, one says this, another that, and based on that, we start going a bit more into details."

Tony adds: "The collaboration was amazing on this project. They brought their German people from Germany so it was really like a Belgian- German collaboration and now us from Austria coordinating these activities and helping them."

The group wants to seize new opportunities for funding a project by answering a call for service robots. They already have some technological ideas based on their previous technological development in a project for easing transportation for people in hospitals. This time, however, they decide to go for a service robot in cleaning. Tony, who takes part in the first meetings (together with Vincent) with important interested parties that can ensure funding, explains that *"when you are in the R&D, the first thing you do is speak with the end-users. So that is only a problem if you don't do it. Sometimes you're thinking, 'let's do something in the cleaning area' but you end up not liking the idea. But in this case, it was the opposite. Everyone liked it. The cleaning provider liked it."*

Both Vincent and Tony feel certain they have invited end-users into the collaboration from the very beginning by making sure everybody likes the idea. From their perspective, the end-users are the big companies who provide cleaning and are ready to pay for cleaning robots in all of their departments across Europe. Yet, these end-users who are top CEOs and company owners will never themselves operate the robots in questions.

As the collaboration developed and Tony and Vincent took on the task of writing the proposal for funding, they began to look for more relevant partners. Several completely new partners were involved as they could provide access to relevant markets.

Yet, the broadened collaboration around developing the robot remained within in inner circle of robot makers: robot developers in charge of the technical aspects, facilitators such as the big companies willing to fund the project and the cleaning manager as application experts.

Tony: "So, this is very important, the ones who are going to buy, collaborate! These companies, they make millions."

Vincent: "I think the German [partner] make more than a billion."

Tony: "Yes, imagine now how many robots they should buy in the future."

Interviewer: "So they're [the partners] already built into the business model?"

Tony: "Yeah, exactly!"

What is missing in this collaboration are the affected stakeholders: the actual end-users, the people who will eventually operate the robots; the directly affected stakeholders, such as employees working next to it and whom may have to change routines so as not to interfere with the paths of the moving robot; and the distantly affected stakeholders, who could be the cleaning staff that will have to find new occupations or education providers who have to teach them new skills, etc.

(Based on statements from Tony & Vincent, robot developers, SPECTRUS)

Similar patterns of not including affected stakeholders in the design phases recur throughout our material. Some robot developers in our case material are, however, aware of the end-users' motives and needs early on, and really strive to include their perspective in their research. Yet, this endeavor is not without challenges as the end-users, and other affected stakeholders, tend to come up with many diverging ideas and the robot-developing engineers are simply not equipped to separate the wheat from the chaff.

On the basis of this observation, REELER researchers identify a need for a two-pronged strategy to close the gaps between affected stakeholders and robot makers, addressing developers' need for ethical education and proposing a new type of collaboration with social scientists.

Thus, we suggest an entirely new category of **intermediaries** which supplement the spokespersons already engaging with the people in the inner circle of robotics by speaking for affected stakeholders. The spokespersons are typically affiliated with the robot makers in one way or another, whereas **alignment experts** like the social scientists in REELER are able to more freely explore potential gaps between affected stakeholders and robot makers.

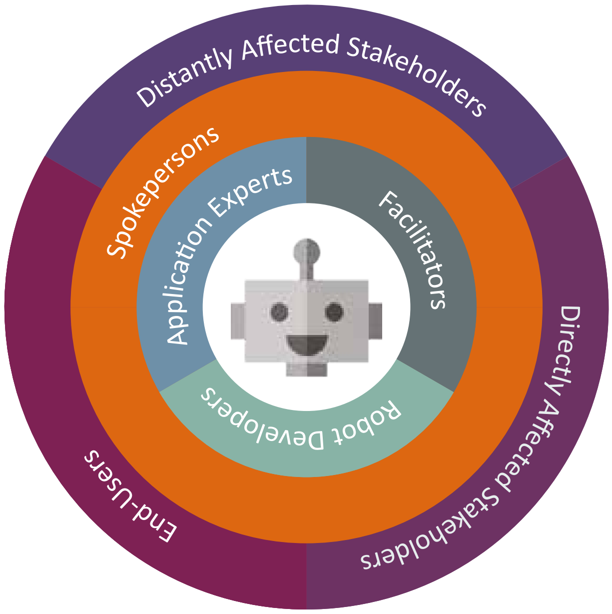


Figure 1.4. Today, the spokespersons (company owners, e.g.) speak on behalf of affected stakeholders (such as workers).

Intermediaries: *Those acting as go-betweens for robot makers (especially developers) and robot recipients (affected stakeholders and end-users).*

Spokespersons: *An intermediary who speaks on behalf of recipients based on their own experiences. Often these people are management level in the same organization as the end-users (e.g., the factory owner speaking on behalf of the workers).*

Alignment experts: *Intermediaries seeking to align robot makers and affected stakeholders based on empirical knowledge of both. Often these people have an expertise in Social Sciences or Humanities (SSH) (e.g., an anthropologist or ethicist).*

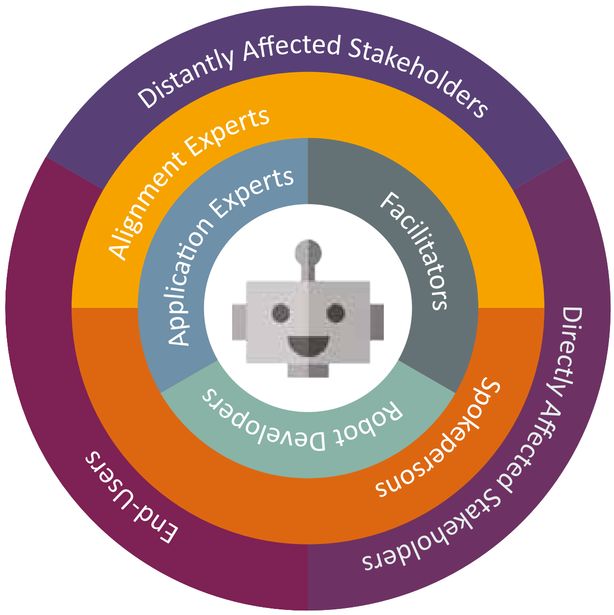


Figure 1.5. Alignment experts can ensure that the voices of affected stakeholders are heard in the inner circle of robot makers.

As intermediaries with close knowledge of both robot makers' practices and affected stakeholders' life-worlds, alignment experts are professionally equipped with tools to bridge the proximity gap and see potential alignment of separate motives.

Learning: *The process of developing material and conceptual knowledge through engagement with a situated social and material world.*

Overall, REELER sees a need for alignment tools and people trained in fostering **relational responsibility** in collaborative learning. This relational responsibility places the responsibility for learning how to make ethical robots on both the robot makers and the affected stakeholders, while acknowledging the need for spokespersons and alignment experts to make it happen. Thus, the complete Human Proximity Model, which includes alignment experts in the circle of intermediaries, is a prescriptive model consisting of three rings: the robot makers developing the robot, the affected stakeholders whose work and lives are changing as a result of the development, and the intermediaries who are tasked with translating the needs and values of the two other groups.

The subsequent chapters build on this model of human proximity, toward more responsible, ethical (and collaborative) learning in robotics.

1.3 Overview of content in Perspectives on Robots

We have divided *Perspectives on Robots* into three parts, each followed by concluding remarks.

Part One: Introducing the inner circle of robotics

1.0 Introduction, is primarily a first introduction to the Human Proximity Model, developed and used in the REELER project for analytical purposes of understanding and mapping the relation between those who make robots and those who are affected by robots.

2.0 Robot Beginnings, explores the catalyzing ideas that get projects started and the driving motives that see them to completion. This chapter demonstrates how familiar beginnings can lead to exclusionary development processes.

3.0 Collaboration in the Inner Circle, forms the empirical grounding for the Human Proximity Model, exploring collaborations in the inner circle of robotics and exposing gaps in collaboration.

Part Two: Enhancing robot developers' awareness of affected stakeholders

Here we introduce empirical findings and analysis that can help robot developers directly by enhancing their knowledge of their own conceptions of ethics, design pitfalls, the innovation networks around their work and the situated practices of users.

4.0 Ethics Beyond Safety, positions REELER in the field of robot ethics with new empirical findings of how robot developers and other robot makers present their notions on ethics, and ends with a discussion of a need for a relational responsibility.

5.0 Inclusive Design, exemplifies some of the ethical issues, and identifies pitfalls, arising from design and wider development decisions (like funding, e.g.), and suggests new, grounded ways of thinking about end-users and affected stakeholders that enhance robot developers' possibilities to make ethical and relevant robots.

6.0 Innovation Economics, discusses the innovation economics systems, which the robot makers engage in, which entail multiple actors engaging in situated everyday practices to bring technological breakthroughs from the research laboratory to the market.

7.0 Learning in Practice, argues that by developing new ways of thinking and pursuing different ways of knowing (about end-users, and other affected stakeholders, as well as about the effect of robots in everyday lives) can result in closer proximity and more ethical robot developments.

Part Three: Expanding beyond the inner circle

In this part, we present issues that go beyond robot developers' ability and responsibility, pertaining to society as a whole, where policymakers have a special ethical responsibility, and where society (and citizens) can benefit from addressing these broader issues. We end by explaining why a two-pronged strategy is needed.

8.0 Imaginaries, builds on the ways robots are represented by media people, some of whom are hired by robot developers and makers, with special attention to the different representations of the robot in popular and news media as opposed to real-life settings, and how media imaginaries created there affect perceptions of the robot.

9.0 Economics of Robotization, presents a large-scale discussion of the future of work, specifically addressing the expected economic impact of robotization.

10.0 Meaningful Work, is a close-up discussion of the many qualitative transformations of work that robotization entails, and the responses to these changes, including resistance, reskilling, and universal basic income.

11.0 Gender Matters, presents issues of gender in design and robotics/engineering culture which, if left unchecked, may contribute to an inequitably gendered society. The point in this chapter is that issues of gender also need to be addressed at a societal level..

12.0 Human Proximity, is one of REELER's primary theoretical contributions and proposes a new solution to some of the issues emerging from the human proximity gap we have identified.

13.0 Conclusion, presents a summary of our findings in REELER and proposes a two-pronged strategy for closing the gaps between affected stakeholders and robot makers.

More online content

A number of supplementary annexes are available on our website. These are:

Annex 1 Methods and Methodology is a detailed description of how we have worked, including how we anonymize all cases and persons interviewed in order to make quotations and stories from the field de-identifiable. This is both to protect our interlocutors and because our cross-case analysis show that the individual person or robot is not what matters, but the patterns identified across cases. It also holds a selection of cases, Nvivo-coding, description of methods applied in ethnographic and economic analyses (*see responsiblerobotics.eu/annex-1*).

Throughout this publication, we highlight the experiences and the voices of affected stakeholders. (Photo by Kate Davis)

Annex 2 Supplementary Quotations. This annex provides insight into the rich body of quotations, chapter by chapter, that underlie our argumentation in this publication (*see responsiblerobotics.eu/annex-2*).

Annex 3 Glossary which lists all the key terms mentioned in this publication with video explanations by the REELER team (*see responsiblerobotics.eu/annex-3*).

Annex 4 Reviews of REELER. Concepts and robot typologies (*see responsiblerobotics.eu/annex-4*).

Annex 5, REELER outreach tools, offers brief descriptions of the online TOOLBOX, the game BUILDBOT, Mini-publics, Social drama & Sociodrama as well as *the game BRICKSTER (see responsiblerobotics.eu/annex-5*).

We hope this publication raises awareness about affected stakeholders and how they might be aligned with robot makers' motives through closer proximity in processes of collaborative learning with the help of intermediaries such as alignment experts.

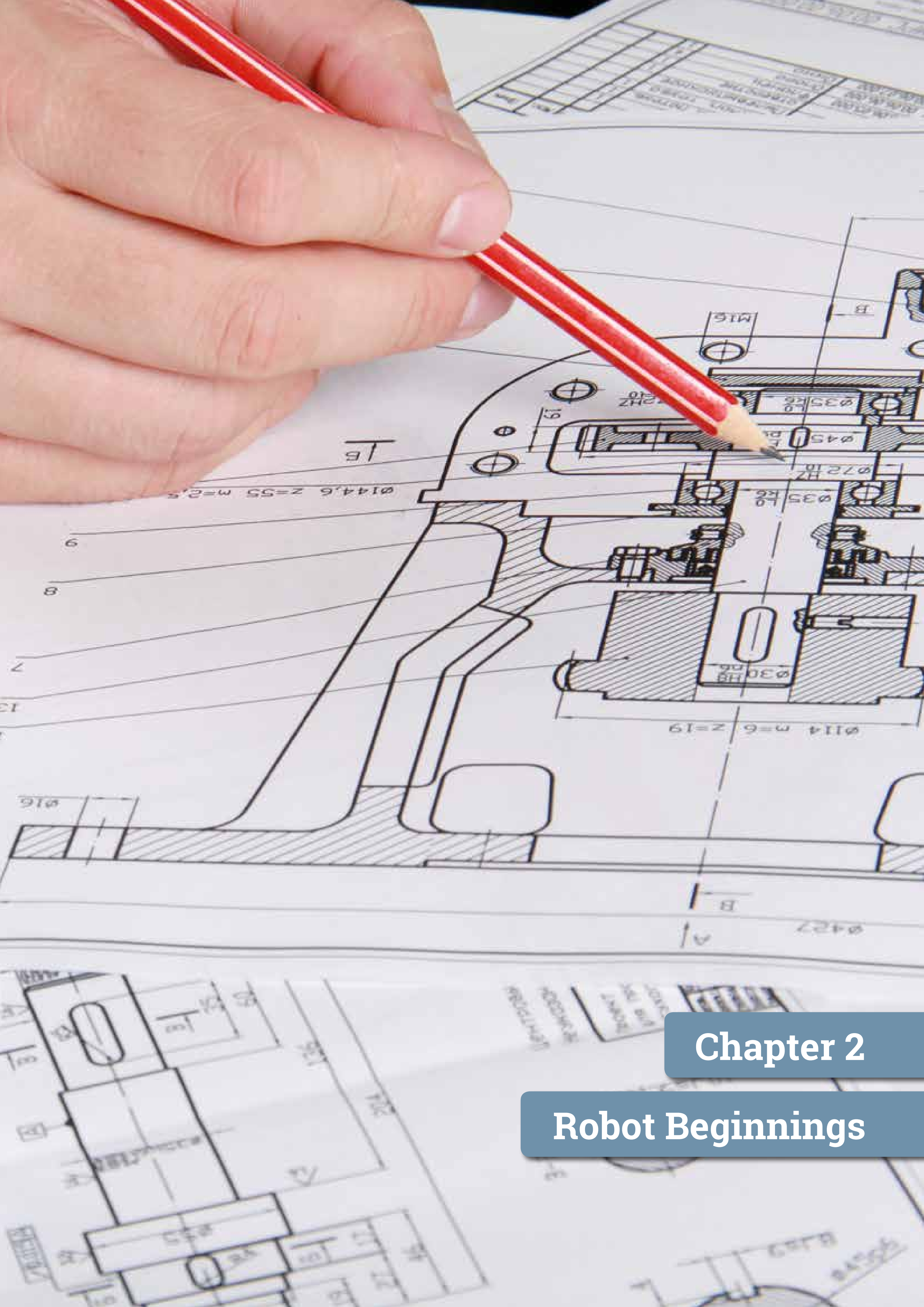
1.4 How to read this text

The chapters can (and should) be read together. Each chapter includes the following features:

You will find – you will acquire: Bullet points summarizing key awareness-raising findings and what the reader can expect to gain from reading the chapter.

Key terms: Central concepts presented in bold face, defined, and included in a glossary in *Annex 3*.

Stories from the field: Narratives based on REELER case examples explaining an issue in a contextual manner.



Chapter 2

Robot Beginnings

Well, you know. I had a mother, who was getting old, and she was living in Como, which is a town close to Milan, but not so close. And at some point, I realized that she needed some help. On the other hand, I knew that she didn't like to have someone around in the house. At that point, it would be perfect to have a system like MoveCare, so that I could connect with my mother and speak with her...This system could help her with a couple of tasks that are fundamental, when people become old. One is the request for help, so that my mother could feel safe at home. She could always call for help, and she could have a system where a robot comes there and connects her with me. The other was looking for things that she was forgetting, more and more frequently. And out of this idea, we started reasoning, and we started thinking that the robot could be paired with other elements, like smart objects, internet of things, demotics... And this system would try to keep my mother from isolation, as she was getting more and more alone as her friends were passing away, and she was not keen to go out so often, and so forth. So this basically was the motivation.

(Alberto, robot developer, REGAIN)

◀ A robot's beginning often frame the rest of development.

2. Robot Beginnings

Why end-users are absent in the early stages of design

You will find here

- An overview of REELER findings of how the initial stages of the robot design and development are tied to different types of ideas and motives
- Specific organizational and individual motives for developing robots
- A critical look at public funding in robotics
- Potential explanations for the absence of affected stakeholders in early stages of robot development

You will acquire

- Awareness of how to engage in critical reflection on ideas, motives, and practices that may influence development in its initial stages
- Awareness of what is necessary for developers to overcome barriers to affected stakeholder involvement in robot development processes

Why do people make robots? How, when, where, and why does the initial idea of developing a particular robot emerge and eventually evolve into a prototype or finished product? We have asked these questions in our 11 ethnographic case studies and in the analysis of the data collected. As noted in the introduction, all of our case-studies represent different robot types and sectors, including healthcare, agriculture, industry, entertainment, logistics, etc. Across these cases we find a lot of variation, but also some patterns in the robots' beginnings.

A key finding from REELER's research is that technology drives development. It is seldom the needs of end-users and other affected stakeholders that is the inspiration or driving force behind robot development. To understand why this is the case, REELER has analyzed the beginnings of each of the robots studied in this 3-year project.

Across REELER's cases, we find that both ideas and motives for developing robots tend to come from what is 'at hand'. When forming ideas for new robots, robot developers often begin with existing robots or previous projects, familiar collaborators and funding schemes. In fact, this is how **innovation** is often defined – taking something familiar and finding a novel way of using it (*see 6.0 Innovation Economics*). Robot developers often collaborate with facilitators (those requesting the robot or providing funding) whose ideas might be the catalyst for development. Even with a shared goal of developing a robot, the actors involved (collectively termed robot makers) may pursue its development for different reasons. The leader of a start-up robotics company might have the motive of attracting investors whereas an engineer from the same firm might have a motive of solving a particular technical problem. Like ideas, their motives emerge from the **sociomaterial worlds** they come from (*see 7.0 Learning in Practice*). Robot makers have learned to align motives with a number of actors within the inner circle of robotics (*see 3.0 Collaboration in the Inner Circle*), but often do not align with affected stakeholders whose sociomaterial worlds can be somewhat distant from their own.

> **Innovation:** *Exploitation of an invention (i.e. using something existing in a novel way). Invention is the discovery/creation of something new.*

> **Sociomaterial world:** *A mix of social, cultural, material, and temporal influences that continuously shape one's framework for experiencing the world.*

This text addresses the ideas and motives in new robot development – the driving forces behind *why* a particular robot is made – and asks whether these robot beginnings are in line with empirically identified human needs and societal concerns. First, we differentiate between ideas and motives and explain how both are informed by sociomaterial contexts. Then, we explore actual robot beginnings based on particular patterns of ideas and motives identified in REELER's cases. Finally, we explore the absence of affected stakeholders in robot beginnings and we consider factors which constrain robot makers from involving them directly.

2.1 Ideas and motives

2.1.1 Ideas

Ideas for robots may come from robot developers, from robot buyers, or from funding bodies, and they often take inspiration from existing technologies, from robot buyer requirements, and occasionally from identified human needs. Sometimes it is facilitators (public funding bodies, e.g.) who have the initial idea for a robot. Very often in industrial robotics, a robot buyer approaches a robot developer with a particular robotization request or collaborates with the robot developer as an application expert to identify an optimization opportunity (*see 9.0 Economics of Robotization, section 9.1.1*). Particularly in robotics research and development, it may be the case that a (public) funding body puts out a call for funding, to which robot developers answer. Sometimes these are open calls or they may be specific to a particular identified public need. It may also be that the idea for a robot comes directly from robot developers, without involving a facilitator. This is often the case with start-ups and with established robotics companies whose focus is on product development.

Thus, ideas for robots seem to emerge only from robot makers within the inner circle. These patterns of beginnings consistently exclude the eventual end-users and directly affected stakeholders, understood as the people who will actually work with or be affected by the robot, from being involved in the initial phases of conceiving robots. We mention this here, because these beginnings are crucial to the way the development proceeds. Robot makers' curiosity and inquiries are constrained by the limits of their gaze, their familiarity with particular materials and settings, previous experiences, and by structural constraints like the need for funding. When the idea originates in the inner circle of robotics – i.e. a particular sociomaterial culture – affected stakeholders and their motives may be excluded from the development process. A poor alignment between robot makers and affected stakeholders can result in many ethical issues (*see 4.0 Ethics Beyond Safety*). Therefore, this text will focus very closely on the patterns across REELER's data that show how ideas for new robots are typically formed, and how one's motives matter in bringing these ideas to fruition.

2.1.2 Motives

Motives are the driving forces for moving from thought to action, from an initial idea to the actual development of a robot. Motives are tied very closely to what is most prevalent in a person's purview: they may be individual like a passion for problem-solving, or may be tied more to organizational needs like getting a product to market to generate a profit. In searching REELER's data for reasons why robots were created, we find two types of motives:

1) *Stated motives*, which are tied more to the ideas behind a robot. A stated motive could be an historical account of how the robot idea formed or a defined purpose of the robot (e.g., to relieve workers of heavy labor).
2) *Object motives*, the underlying reasons for the development activity – E.g., developing a robot to get a product to market (to make money).

There can be many different motives for doing one's work, but here we focus on the *object motives* – those that direct one's activity toward a particular shared goal.

In robot development, how a robot is perceived or interpreted by a person or organization shapes their motives in the development process. Anne Edwards writes that the object of an activity gives it its direction (Edwards 2007, 7). In robot development (the *activity*), the robot end-product is the shared goal (or *object*). "The idea of object motive importantly recognizes that our actions are elicited by our interpretations of the object" (Edwards 2007, 7). Therefore, a robot developer forms his (most robot developers are male) motives based on his own understandings of the robot as an object of development activity. Whether he considers the robot a research problem to be solved or a product to be brought to market will affect the decisions he makes in the development process (Sorenson 2018). His motives emerge from what is at hand in his own world which has been molded and bound to some extent by his disciplinary background.

In analyzing REELER's data, we find it is not only robot developers who direct development activities. Because robot development often involves many different individuals and organizations (*see 12.0 Human Proximity*), there may be a plurality of motives compelling a single robot into being. Robot buyers, for example, are often involved in development and may take on different roles even while their motives remain the same (*see Figure 2.1*):

- As **end-users**, who will buy and use the robot themselves, they create market demand or define requirements for a customized solution.
- As **application experts**, who are part of a project team, they give input on application-specific manual processes, workflows, or the robot's surroundings.
- As **spokespersons**, brought in as 'end-users', they give feedback on the design on behalf of actual end-users.

The robot buyers' object motives – the reasons for performing the aforementioned roles and taking part in the associated activities – may differ from the robot developers' reasons

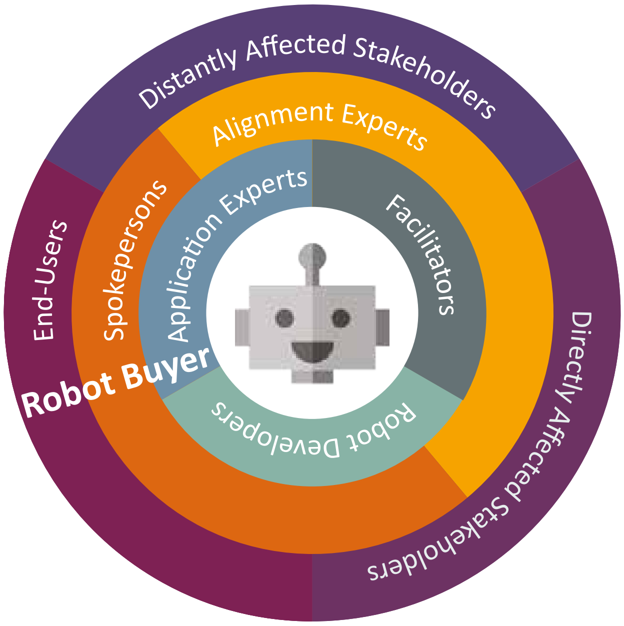


Figure 2.1. Robot buyers can take on different roles in development.

for their role in creating a robot. In working toward a shared object, these robot makers must learn to align their collective motives (*see 12.0 Human Proximity*). Generally speaking, a person's motives are formed from the *sociomaterial world* that person inhabits. However, a person does not exist alone. Rather, a person is embedded together with other persons and materials in a shared social and cultural space created from their interactions. In these interaction spaces, worlds collide and are permeated by new information/experiences, transforming the individual worlds and complicating separate understandings of the object. Therefore, one's own world is not fixed, but is constantly adapted through experience –which also means that their motives, which are shaped by their world, can transform.

Further, our cross-case analysis identifies a difference in shared *organizational* motives and *individual* robot developer motives. Although there is some overlap between organizational and individual motives (after all, organizations are composed of individuals), for analytical purposes we will first discuss individuals followed by organizations, as we present particular patterns of ideas and motives identified in REELER's cases.

2.2 Individual motives

REELER interviewed robot developers about how they first became involved in robotics, how their specific projects got started, and what the purpose or goal of the robot is. What we observe is that robot developers' work begins very close to home, driven by their own *passion for robotics* and a dedication or confidence in their *previous work*. These are the object motives we observe in nearly every project. However, we have also gathered *stated* motives – i.e. the reasons robot developers give for making robots. *Doing good* is a primary stated motivation – which is something we acknowledge but also dissect in section 2.2.3 (*see also 10.0 Meaningful Work, section 10.3*). Of course, whenever a person is engaged in paid labor, making money is a consideration and a motivation – but we rarely see money as the motive that really drives an individual robot developer to continue his everyday work.

2.2.1 Previous work

The most consistent pattern across is one beginning with an available technology, and people who have already formed at network around this technology along with funding opportunities. Sometimes the idea of the particular robot forms the basis of the founding of a new company, at other times the new robot is developed within an established company in search of new applications for an existing robot, or an established company with many technology projects, who venture into a new field of robotics.

In some cases, new ideas and projects in robotics are the continuation of previous projects that were carried out by a given group of robot makers. Previous work also refers to networks that robot makers are part of. Continuation may refer to addressing a similar subject as well as involving a similar consortium or a group of collaborators (*see Story from the Field on design and development processes in section 2.4.3*). On the one hand, such an approach helps building on the previous knowledge and experience as well as further develop one's expertise in the robotics field and a related community. This is particularly important in a situation where the design process and collaborations are distributed between different persons, locations and phases; where it may be difficult for a single person to have a complete knowledge of the project history and related developments (*see Story from the Field on distributed ethics in section 4.3.1*).

2.2.2 Passion for robotics

It is clear that passion for robotics runs across all cases in our study. The robot developers are passionate about building robots and have a lot of fun doing it. A number of the interviewed robot developers point to their personal interest in constructing robots as the main motive for developing robots.

> *Interviewer: And how would you define a robot?*
>
> *Daniel: I would say tool … versatile, especially for humans. Passion obviously for me, I am very passionate about robotics.*
>
> (Daniel, software developer, robot developer, BUDDY)
>
> *Here I am really in my element, that is my passion, and I am really blooming here. And because of that, I believe, I can perform well in my job.*
>
> (Stefan, mechatronics engineer, robot developer, COBOT)

In many of our cases, we see that robot developers really love their work and would not give it up, even for a universal basic income (*see 10.0 Meaningful Work*). Robot development has a level of playfulness to it that can best be described as puzzling. Engineering is largely problem-solving work and in robotics this work takes a very physical form where a developer's decisions on a computer screen correspond to real action in the world. Observing robot developers at work is not unlike observing children at play. They can become completely absorbed in solving a particular technical challenge through creativity and innovation. In fact, some of this playfulness is cultivated in robot competitions, which some robot developers engage in especially at the early stages of their careers. In addition to being fun, robot competitions also often serve as an important starting point to attract the interest of mass media and potential partners or investors, as well as to give confidence to robot developers to pursue their projects further.

Robot developers often start with their own interests and experiences, which can be very good for society if the interests are aligned with societal needs (like Alberto building a robot to support his elderly mother's independence). In research-oriented development, we see robot developers have more freedom to follow their interests, whereas they are more constrained by the product- and customer-oriented developments.

> *It is not so easy to find such a job where you can be pretty free as a developer. So, sometimes you have pretty narrow requirements and you only hear: "Optimize this in this and that direction". And here you can come up with a new concept, build that up and figure out does it work, does it not work. And yes, that is exciting.*
>
> (Valerie, mechanical engineer, robot developer, COBOT)

For those who enter product development, we see that they try to find a way to blend their passion and individual interests with the monetary interests demanded at the organizational level, though sometimes they must compromise their own ideas to meet market demands.

> *I mean we fairly early on said: "Yeah, we want to do that and we want to build [an autonomous car] as a service and we want to do it in the urban environment because that's cool and interesting and fun and it's where actually you can have the most impact generally." And then, for various reasons in terms of funding, we had a period where we said our go-to-market was going to be more a licensing business, but we always kind of felt our heart was in the service business really.*
>
> (Sebastian, CEO, robot maker, HERBIE)

Across cases we see that this problem-solving activity is not only applied to technical challenges, but that robot developers are also interested in solving human or societal problems with technological solutions (Sorenson 2018). This ties into another motive, *doing good*, as seen in the autonomous car example above.

2.2.3 Doing good

Many robot developers report doing good or having a social impact as a motivating factor for developing new robots. However, when we look across the different stages of robotics, we see that the *ideas* for building robots are seldom motivated by meeting others' needs. Here, we rely on the distinction between *stated* motives and *object* motives. Doing good is often a stated motive – that is, it is a factor in their thinking about the development, but it does not drive the development. If it were not possible to 'do good', the development would continue (*see 10.0 Meaningful Work*). Put another way, it often turns out that a robot is incapable of fulfilling the good it was intended or promised to do.

This was the case of the robotic start-up in the logistics industry whose founders decided to deliver robots that are 'affordable to all'. At the same time, the company would carefully target its customers and engage with B2B marketing.

> *So, the idea of the company is actually to create robotics that are accessible. It's not as expensive as people — I mean, it's still not going to be cheap yet, but it is acceptable and it's affordable and more companies can employ robots. (…) It's not just working for giant companies who really can spend millions on automation. Our idea is affordable robotics for people.*
>
> (Alph, start-up CEO, robot maker, WAREHOUSE)

Although they could not make the robots affordable for all, they did continue to follow their mission to develop robotic systems that benefit people. However, this company was largely founded on external Russian capital, which puts organizational needs for profitable investment and individual motives of affordable robots somewhat at odds. This case is a good example of product-oriented design thinking being focused on robots as 'solutions'; both in the sense of performing tasks but also as solutions to specific problems people might have within their organizational cultures and environments.

> *Design again, the idea is we do robotic solutions. We do the solutions to help people to work. And then, okay, what's going to be our first application of this attractive solution.*
>
> (Alph, start-up CEO, robot maker, WAREHOUSE)

Whether the market-oriented approach actually brings robots to the market for the benefit of end-users and not prevalently for commercial benefits, depends on the priorities assigned by robot makers and our socio-economic system as a whole. Even with the many good intentions to create robots for people, the robot makers still lack a closer contact with the actual people they envision to help out in their everyday lives. Even if robot solutions may be profitable for a company this is not the same as helping people on the shop floor (*see section 2.3.2; see also 9.0 Economics of Robotization*). Sometimes, individual robot developers aims are complicated by structural factors and other patterns of activity.

When individual robot developers' activities are driven by or constrained by the strategies of the company, institute, or university they work for, we call these forces organizational motives. Just as individuals comprise an organization, individual motives underlie the ideas and motives of organizations, which are presented in the section that follows. Therein, we see that previous work, passion for robotics, and doing good are all integrated into the work done on an organizational level, but are subservient to the overarching organizational motive of making money.

2.3 Organizational motives

> **Business case:** *An argument for robot development based on expected commercial value.*

Across REELER's cases, we find that robot developers have different motives for designing robots, which are not all tied to bringing a new type of robot to the market. However, given the nature of the industry, all of the robotics start-ups and companies studied within the REELER research followed commercial objectives to a varying degree. Other organizations may start their activity or specific robotics project with a clear profit motive in mind. While still others are approached by a customer with a particular need for a robot. Finally, there are those who focus on research experiments or the research side of full product development. Such an approach involves not only the decisions of robot makers but also the motives of those providing funding and/or interest on the investors' side. In such a case, business interests are closely related to design interests and the two evolve together.

> *Many times, we develop the business cases, we develop the robot, because then we also make adaptations to the robot design and the specifications regarding that. I think, when we started, we had a basic business case, as we had a basic concept of robot and I think both evolved side by side.*
>
> (Oswaldo, industrial designer, robot maker, SPECTRUS)

In REELER, we categorize the robot beginnings in our cases as:

- *Product-oriented*, where the robot emerges from ideas for new product development or expanding to other applications or markets, from which the organization expects to make a profit.
- *Customer-oriented,* where a customer initiates development and comes with requirements for a robot, from which

the robot development organization expects to generate revenue.

- *Research-oriented*, where the robot is initiated from calls for funding and the aim is to explore new applications or functionalities in robotics.

In product-oriented development, it is often the robot developers that come with a new idea for a robot, whereas in research-oriented development, new robots emerge because robot developers tailor their robot idea to a specific call for funding, similar to when robot developers are approached by an 'intermediary' like a robot buyer with specific demands. In all cases, whether intended for mass production or answering a particular demand, all organizations have to keep an eye on the bottom line. Unlike individual robot developers, organizations' motives largely concern earning money, though they may go about it in very different ways (i.e., profiting from sales, securing research funding, or generating revenue from services provided to robot buyers).

Sometimes, a single robot project can involve multiple organizations spanning these three robot beginning types (e.g., a research-oriented institute or university developing a prototype robot, a private company commercializing the robot, and a customer giving input on requirements and perhaps implementing the robot). Even when a robot is developed outside of these coalitions, perhaps in a robot company alone, public money is nevertheless often traced to development activities. That is to say that public money is heavily invested in robot developments of all types, in all sorts of settings, and dispersed to all sorts of organizations.

2.3.1 Product-oriented

The motivation to generate profits through new product development entails a desire to put a product into production and sell it to a wider market. This is an approach to robot development that is initiated by robot developers with the motive of turning a profit. The product-oriented approach is especially common among established robot manufacturers, but was also common to start-ups. The start-ups tend to have a passion for robotics and a desire to churn passion into profit. Large companies have different types of resources that allow them to turn their ideas into actual products (often branded under the umbrella of 'innovation'). In fact, large robot manufacturers often invest in R&D on a continuous basis through their own R&D divisions, and sometimes in collaboration with public funding bodies or in affiliated research institutes. From this perspective, a single organization may be project-oriented but may nevertheless engage in research, inasmuch as it contributes to new product development or strategic competitiveness.

The product-oriented approach is developer-driven and organizations that are focused on product development have a tendency to begin from what they know. New product development is often cultivated from existing technologies and product lines, involving familiar players. Similarly, a lot of start-ups and robot companies emerge from university researchers' existing collaborations.

STORY FROM THE FIELD:
Commercializing innovation

One example comes from a group of young robot developers who have successfully developed an educational social robot. This group included persons who knew each other from a robotics department and related activities at a university. While affiliated with the university, the group became involved in robotics competitions. The first shared goal the group set for themselves was to deliver a proof-of-concept and demonstrate feasibility of their solution. The group successfully displayed a robot resembling a sumo wrestler at a national competition. While the judges and the audience (including would-be investors) appreciated the technical side of the solution, they also criticized the aggressive aesthetics of the robot.

We created the first version of the robot which very much reminded a sumo wrestler and we managed to win one of the local competitions with this robot. Everyone was delighted with the solution. But then people approached us in the lobby, they patted me on the shoulder and said: "Well, a great solution, but do something with its look – it doesn't look nice." (Matis, co-founder & marketing, robot developer, ATOM)

In order to exploit the initial success of the robot and to engage further in robotics, the robot makers decided to set up their own start-up.

We won the national finals. And immediately, when we sat down to the project, we decided we wanted to make a product that we were going to develop that was able to achieve some business potential. Participation in the competition allowed us to acquire the first investor, which allowed us to bring the entire product to production readiness, and at the same time to get the partners we wanted. (Matis, co-founder & marketing, robot developer, ATOM)

We invested all our savings [laughs] at the development phases. At the beginning, we wanted to have a try to see how it goes. As it turned out, let's say the idea itself caught on … enough to decide to invest in it both time and money. At some point we decided to make a business out of it. (Leon, co-founder & CEO, robot developer, ATOM)

Gradually the company manage to attract significant private investments (with only limited participation of public funds) and the start-up began scoping out the market for a potential application. The robot had begun not as a product, but as a provable concept, but along the way the robot developers got feedback from different people that influenced the final design. They were not able to identify the exact moment that their idea became centered on educational robots, but by working together on the prototypes, the idea for ATOM gradually became clearer.

If we go back in time to the very earliest days. At the very beginning, the idea was to try to combine IT education or IT experience with the robotics experience that people in our team had. And initially, we wanted to try to bring a computer game to the real world, so that instead of playing on a computer screen, it could be done on the larger room floor. After a few modifications we came to the conclusion that we should try to teach children something and we came up with the idea of an educational robot with a strong focus on entertainment. Our first concept was to create the robots that were going to fight with each other. (Leon, co-founder & CEO, robot developer, ATOM)

The start-up's market-oriented motives led them to making repeated modifications to please their target buyer group.

The children would program robots so they can fight. For children it's a game. But for parents, not really. And there we were getting information whether we should soften it, trying to keep this entertainment aspect and smuggling some education underneath. But that it would not be something that can be associated with negative emotions. Therefore, in subsequent iterations of the project – the next modification was to create a robot that was going to teach children the basics of programming and develop the ability of logical thinking, but of course ensuring competition, too. So elements that allow children or encourage children to work longer with the solution, not only to play with it 15 minutes and put it in the closet, because all functions were already recognized. And it was one of the key stages related to the fact that we brought our idea to a certain point where we knew, and all agreed, that it was it and where the market response was also: "Ok, we want it." (Matis, co-founder & marketing, robot developer, ATOM)

In this product-oriented approach, the focus in the robot design was building a technology which could sell. The focus was not the application, nor the end-users' (the children's) needs. Part of the success of the company and its product was in the relative early phases extensive engagement with end-users and collaboration with other experts that helped creating the robot. This is how, while initially starting from their own individual interests, robot makers shifted their perspective towards user- and market-oriented design thinking to further design and develop a social educational robot.

(Based on interviews with Leon, co-founder & CEO, robot developer and Matis, co-founder & marketing, robot developer, ATOM)

A similar approach was followed by a small group who set up a robotic start-up in the area of logistics. The goal was to see if the solution they had in mind was feasible rather than to meet specific end-user needs. As in the case of the educational social robot, this group of developers initially invested their own funds and developed the first prototypes in their own apartment and garage – with an eye to eventually create a marketable product and a viable business.

> *So, the guys realised we can make it work. That was the first conclusion. The second was, if we can make it work, then we have to actually make it more than just a hobby. Then it becomes part of the foundation of a start-up or foundation of the business.*
>
> (Felix, CEO Advisor, robot maker, WAREHOUSE)

As pointed out by one of the robot developers in the educational social robot start-up, in order to be successful, the idea for a product must be supported by thorough market research (which includes the assessment of the customer requirements) and not simply be based on the convictions one might have.

> *First as we develop research, we investigate the market and try to develop a product according to customer requirements. And as a result of this process, we have a so-called ideation; the creation of an idea. Then we ask ourselves and the customer a lot of questions, we do a brainstorm that leads us to the final form (…) And always the design is a solution to some problem, it is an answer to a question (…). There are always some design assumptions. (…) The design process does not begin with the fact that a designer has a robot in mind and sketches it, it is always backed up by some research. Research and customer requirements, in particular the functional requirements for that object.*
>
> (Igor, design studio, robot maker, ATOM)

While such approaches initially are far from the user- and society-oriented design thinking, market-oriented start-ups and companies inevitably have a strong desire to see their robots being accepted in the public. Therefore, closer collaboration with the actual end-users (not just potential buyers of commercial robots) in the early stages of design could be a benefit to the budding robot developers. As illustrated in the above quote, however, we see across cases that robot developers tend to conflate customers/clients with end-users.

Thus, product-oriented organizations tend to spin new ideas from within the organization, relying on the same network of players and beginning with existing technologies or past experiences (*see section 2.4.1*). Sometimes, these approaches involve market-research with potential customers to define the robot's design and/or application. However, these insulated beginnings often omit the end-users and their motives from being taken into the design process (*see section 2.4.3*).

2.3.2 Customer-oriented

Just as product-oriented development is focused on making profits, the development of robots for customers is driven by a desire to generate revenue. The customer-oriented approach (sometimes called 'commercial development') differs, however, in that each robot system provided is a one-off solution that is tailored to a single robot buyer's needs. The customer-oriented approach is most common among research institutes and system integrators in industrial automation. This approach was also surprisingly found among Silicon-Valley style start-ups, whose goal is to develop a working robot prototype and validate the market for the product with the purpose of being acquired (or selling off the fledgling product idea). In all cases of customer-oriented development (among research institutes, system integrators and these particular start-up types), the initial need for the robot originated from the robot buyer. This means the robot developer must contend with the buyer's motives, which are usually tied to competition – whether this means remaining cost competitive through production rationalization, or remaining strategically competitive by meeting social expectations of digitalization *(see 9.0 Economics of Robotization for a detailed discussion).*

In this chapter, however, we focus primarily on the motives of the robot developers, and in this section, why they engage with robot buyers to create customized robots, and how they are able to make a business out of this approach.

In METRO, one of the robots in the OTTO case, a robot developer was approached by one of the leading providers of metro services in a particular European country. The two organizations had an established relationship, having already collaborated on other occasions. Together, the robot developer and robot buyer identified a problem that could be solved by automation. As pointed out by one of the robot developers, customers typically come with a problem to be solved and not with a concrete idea for a solution.

> *Interviewer: Did they come to you to ask to develop this robot?*
>
> *Bart: No they asked us to develop a solution, because a customer doesn't know the solution; he only has a problem.*
>
> (Bart, business developer, robot maker, OTTO)

This is typical in industrial automation (e.g., in manufacturing and production), but also in inspection and maintenance, agriculture, and other sectors where specialized machines have traditionally been used to automate tasks. With an increase in service robot applications, we also see customer-oriented development in healthcare and hospital settings.

Often, a potential customer approaches the robot developers, or the developers send consultants to the company to examine a work process and identify a task particularly suitable for automation. With the problem defined, the company comes with requirements for the solution, from which the developers draw up specifications. So, while the development may be initiated by either the developer or buyer, the choices in development are heavily influenced by the buyer and the buyer's motives.

It is important to note that the robot developers in the OTTO case did not have any knowledge of metro systems prior to their collaboration with the robot buyer. This is often the case in customer-oriented development, in which the robotic company learns about the given field of application only through the development process – not before. Thanks to an open and collaborative approach demonstrated by both parties and extended periods of time spent together in the field with the actual metro workers, the robotic company managed to design and adjust robots in a way that met the requirements of the metro service provider as well as the workers involved.

> *We started with a structure of tubes, with the prototype Zero [laughs], or rather below zero, and from there we began the adventure that really in the last few years has led us to do hundreds of tests. (...) Of course by bringing some of my knowledge to them because they arrived completely ignorant on the subject, they basically did not even know what they should be looking at. Because the sector was completely new to them. So, they made a significant leap of knowledge.*
>
> (Bart, business developer, robot maker, OTTO)

Involving people with contextual knowledge of the application area is crucial for starting the design process with a shared understanding of a problem and in aligning expectations that might later translate into actual robot features and functionalities. An advantage of such close collaboration between robot makers and robot buyers is the opportunity to gain first-hand, on-site knowledge of the process to be automated. However, just as in product-oriented development, customer-oriented development may be insular, involving only those people who have already entered the robotic bubble – the inner circle of robotics. We have seen across cases that these customized commercial projects often start with participation of *intermediaries* like the company manager who is in the position to articulate the company's demands, or a production engineer who might have insight into requirements or specifications for the robot – but this does not mean that actual end-users or robot operators are included. (With METRO, however, this was not the case. End-users were consulted often and early on.) We argue that approaches where a robot meets the customer's demands is not necessarily the same as applying an end-user-oriented approach. And, for many product-oriented robot developers, it is *only* the robot buyer's needs or requirements that matter in design – the actual users' needs simply are not a consideration. In fact, the buyer's needs and the end-users' needs may be at odds if, for example, the buyer is acquiring the robot to automate part of the end-users' tasks (*see 10.0 Meaningful Work*). What is important in robotics, and what is as yet unaddressed, is the need to align the motives of the robot buyers and the robot developers with the needs of the users. Persons expected to use the robot ought to get some say in setting the requirements.

Publicly funded projects are often expected to promise some kind of market potential, even if the motivation is research.

2.3.3 Research-oriented

A third group of organizations develop robots primarily on the basis of research funding, which occasionally becomes a satisfactory way of earning a steady income. The stated motive of research-oriented development is to advance the field of robotics, while the object-motive of organizations engaged in research is the funding that drives many of the research institutes and technological development companies that rely heavily on research funds to cover the costs of their daily operations.

We also see research in large successful companies, even if research is not their primary motive. For example, one large company which was not specifically involved in the REELER project, but illustrates very well an archetype in our research, is a robot manufacturer with an established industrial robot product line, but which invests in R&D. Most of the robots coming out of these processes are not meant to go to market, but are used in marketing and contribute to the company's brand image. Although the company describes their core product line as industrial automation solutions and their products page features components such as actuators, motors, controllers, and sensors, their social media channels feature exotic robots from their experimental R&D division, with zoomorphic and anthropomorphic features. These robots are disproportionately represented in media campaigns, especially considering that less than ten percent of the company's turnover is invested in such R&D. Although not intended as products themselves, marvelous machines boost the company's product-oriented business. The imagery the company produces demonstrates an interest in maintaining an image as an innovative organization (*see 9.0 Economics of Robotization and 8.0 Imaginaries*).[1]

This type of R&D activity is different from research-oriented organizations whose primary goal is research. In product-oriented organizations, R&D still feeds into new product development – where breakthroughs in lightweight sensors in the company's biology-inspired robots might be taken up in industrial automation, e.g. Nevertheless, we see an entanglement of product-oriented organizations with publicly funded research.

Although research is a phase in product development, the major differences between product- and research-oriented development are the source of the idea and the object of the development. Research projects usually are framed by some sort of call or funding guidelines which may already delimit the application areas, sectors, or problem area that the robot should solve. Some research projects are not unlike the customer-oriented robots, formed around a buyer-defined need, except that these projects are publicly funded and the resulting robots are typically prototypes or experimental solutions – not products that will be scaled.

In this context, one of the REELER cases involves a cleaning robot developed for the hotel industry. The robot was created by a start-up and a spin-off company that later became a part of a local cluster bringing together academia and industry. The cluster has been created with the support of both a local university and local government funds. In this sense, the company was part of the deliberate efforts and investments made on the side of the government to strengthen the robotics industry and its collaborations in a region. The robot began from an open call from hotels and regional tourism authorities for cleaning technological solutions. The design and development started from developing a concept and a business plan, to later creating a prototype, and the company does hope to eventually have a market-ready product (scalability and commercialization were part of the grant proposal).

Although the robot was built upon an existing mobile platform, the entire process took several years before the robot was ready for implementation (and it is still being fine-tuned although it has been implemented in a few hotels). In this case, the entire project was strongly bounded by national frameworks, both in terms of funding sources, participating tests sites, and the outcomes of the project. As it turns out, the robot did not prove transferrable to other hotels outside of the European region where it was designed (see inclusion/exclusion). Nevertheless, the start-up continued to make new robots, many of them funded in part by public research funds, with similar results.

Research-oriented robot development blends organizational interests with public and private interests. Thus, there are multiple motives at play. At any given time, the start-up that made the hotel robot had five or six publicly-funded research projects running. This is a pattern we have noticed in research-oriented organizations. Research funding becomes a dependable revenue stream for some players. Depending on the source and type of funding, such an approach may foster specific forms of collaborations and problem-spaces that may be limited to only specific networks, cultures, and design practices. Once again, there is a risk of development occurring within a specific 'bubble' where robotics projects are initiated with very little consideration for the perspective of the actual end-users and affected stakeholders.

2.3.4 Blurring the lines

Whether organizations intend their new robots as products, as services to customers, or as research experiments, the robot developer organizations are all driven by making money. While there is nothing wrong with an organization having monetary interests, REELER finds that public money is often involved in robot development no matter the organization's standing as a private company, research institute, non-profit. Public money is heavily invested in robot developments of all types, in all sorts of settings, and dispersed to all sorts of organizations under various commitments and conditions. This means that public funding is also implicated in the many ethical issues REELER identifies in the other chapters.

We see private robotics firms taking part in publicly funded research projects, or getting their own start from early government investment in robotics. We see research institutes and other technological development organizations living from project to project, paid by public funding. We also see automation experts partnering with robot buyers to seek public funding to offset labor costs for developing customized

1 For a brief explanation of R&D for publicity, see: Metz, Cade. 15 October 2019. If a Robotic Hand Solves a Rubik's Cube, Does It Prove Something? *The New York Times*. https://nyti.ms/31hLzLp

solutions. All of our cases fit these three archetypes to some extent, though money is rarely stated as motive.

REELER interviewees rarely mention funding as a reason for taking up robotics. Still, we find that ideas and motives are tightly coupled to earning money, and we find that the boundary between the public and private sector, and related funding, is often far from clear. Nevertheless, the financial basis of 2 of 11 REELER cases is solely public funding and for the remaining 9 cases - irrespective of whether the work is conducted by private companies, research institutes, or universities – public funds have supported the robot projects. And some projects can be extended repeatedly for years without the robots ever coming to market.

It is important to note that public funding schemes often encourage commercialization of robotic technologies as a way to bring robots to the society – but as shown by the REELER data, public funding is not naturally or overtly connected to product-oriented development. When the same groups of robot developers are funded over and again, robot innovations that were meant to be disseminated and to contribute to economic growth, never actually leave the lab. The technologies of one project become the basis for the next. In this sense, public funding schemes are gradually becoming a sort of business.

> *I think we can have some nice opportunities, because the European government provides a lot of money in case of European projects. The only problem is that these kind of projects, ten years ago were really easy to access. Now it has become a business, so now there are persons – lawyers really – that just do this job; to support a big company to achieve the money, to take the money from the European project. And so, the small company does not really have the opportunity to have the kind of economical support.*
>
> (Alessio, Start-up CEO, robot developer, COOP)

In overtly public research projects, robot makers often respond to specific funding calls that determine a problem which requires a robotic solution. In this sense, the responsibility for design ideas and the consequences of design also falls on public funding bodies, including policymakers. Whether these funding bodies have a good understanding of citizens and societal needs is an open and necessary question. If public funding has such a heavy hand in determining the forms that robots eventually take, great care ought to be taken to ensure that these investments serve the public good.

Investment of public funds in robotics has been going on for a long time. Take the case of one major industrial robot manufacturer studied in REELER. The history of development of their robots started at a big public research institute that has been exploring different areas of transport and automation since the 1980s. The institute's work was initially focused on the development of lightweight robotic systems for different areas of the transport industry. Starting from the 2000s and with the support of publicly funded projects, first steps were taken to transfer the lightweight robot technology from transport applications to potential industrial applications. The transfer took place between the research institute in question and a private company with the goal of commercializing its product. The two are closely connected as some of the company employees used to work for the institute and they are located in close geographical proximity. The company in question has a long record in the field of metal fabrication. Over decades, it has become one of the world's leading companies in automation of industrial manufacturing processes. One of the main reasons for the company to participate in the transfer was to meet the demand of its main customer who was pushing towards development of lightweight manufacturing robots. It is important to note that given the novel nature of robotics technology at the time, the company heavily relied on public funding.

Public funds are often framed as investments in emerging technologies or innovation. Often, the justification for such investments is a promise of shared value from commercialization and consequential economic growth. Many public-private development projects promise accessibility, scalability, generalizability – basically that robots should be more widely available. However, in practice, REELER research shows that in many research projects, these goals are often a mirage. Thus, it may even be unethical to make these kind of promises when searching for public or private funding – especially where this behavior obscures unmet user and societal needs. The involvement of public money in robot development has not been uncommon and is confirmed in REELER's cases. But now, we contend that stakeholders are due their return on investment.

2.4 Absence of affected stakeholders

In this section, we unfold the apparent absence of affected stakeholders in robot beginnings, starting with an explanation of the familiar beginnings which so often influence the ideas for new robot development. Then, we look at the distributed nature of development and how it can be difficult to involve end-users when development is geographically and conceptually dispersed. Finally, we take a critical look at Technological Readiness Levels (TRLs) to distinguish between 'invention' and 'innovation', in order to explain how the end-user is not – or perhaps cannot – be involved in the earliest stages of technological development.

2.4.1 Familiar beginnings

All of the robots studied in the REELER project began from familiar beginnings – whether from previous collaborations, from existing technologies, or from problems already identified in past projects. When starting from what they already know, developers run the risk of isolating themselves from unfamiliar problems and unfamiliar affected stakeholders. While this approach results in a more well-defined beginning, the choices already assumed in early design stages close off other design choices and problem areas that might have led to very different development processes.

Robot developers often try very hard to engage end-users in their design processes, but familiar beginnings can render their efforts inert. In general, across different industries, robot developers face the challenge of achieving a balance between exploiting a technology and bringing end-user expectations to the table.

When you are working at the age of research, the matter is more complicated. Because on one side, you still need to know the wishes and the expectations of your customer, it may be a clinician, or it may be the NGOs. But at the same time, technology may be more advanced in development than the expectation. So, it's a continuous tuning of technology and expectation. And you need to have both the researcher and the user together. And if you are able to have them working together since the beginning, you are able to exploit, the maximum, the potentiality of the new technology. Otherwise, no.

(Alba, head of R&D, robot maker, REGAIN)

However, several robot makers deny that the demands should come from the affected stakeholders, as they know too little of the potential of the technology.

Sometimes the customer asks a lot of things, [that are] not really necessary. And our goal is to explain to the customer which of these customizations are really important to the solution.

(Luciano, software designer, robot developer, OTTO)

At the same time, European robotics can sometimes appear to be a 'small world'. Despite efforts to bring technological and economic innovation to all European countries and facilitate their participation in robotics initiatives, the robotics projects and related design and development processes are often distributed among only limited networks and locations. Such an approach may increase bias in design thinking, situated in specific national and local socio-cultural contexts as

Many robots start with familiar beginnings, like previous collaborations, existing technologies, or previously identified problems. (Photo: Kate Davis)

well as narrow the perspectives robot makers take towards the affected stakeholders and robotic solutions. For example, one of REELER cases has shown that both robotic companies and university laboratories tend to prefer to collaborate within a relatively stable, homogeneous network of partners, in particular those located in the country where the company is based. As part of this case, one of the customers located outside Europe decided to pursue robots produced by a given company because, unlike some other producers, the company in question made its robots available on the customer's continent. This illustrates how not only the world of robotics may be small, but also the world of its customers.

From this perspective, one explanation for a lack of close contact and cooperation with end-users and affected stakeholders might be the insulating process of starting within specific circles of the robotics field and industry. However, it is not so easy for robot developers to simply enter into a community of practice and together identify problems to be solved by technological means, as shown in the sections that follow.

2.4.2 Distributed beginnings

Despite the intentional variation across REELER's eleven cases, we find a pattern in the way robot makers develop their ideas and the groups they form. As noted in the introduction, when we chose the sites of ethnographic work, we selected for variation in not just robot types, but also organization size, application sector, and countries. Initially we worked under a misguided – or normative - perception of how robots develop from idea to product: We envisioned that a robot, whose origin appeared to be tied to a European organization, would be developed in one place within the borders of Europe. Instead, we found that most robots develop in very international collaborations. In fact, of the 11 cases, one robot company actually turned out to be headed and founded by Russians, another has roots in China and another was at least initiated by South American developers. In all of the other robot cases, at least parts of the robot are delivered by countries outside of Europe like Japan, USA, and South Korea. Though the finding may seem banal, across cases we find that no robots are developed from scratch in a single place. A robot is a distributed technology, built from many different components manufactured all over the world, and sometimes involving modifications or additions to an already developed robot (like industrial cells built around off-the-shelf arms, or mobile robots built upon existing mobile robot bases). In all of these cases, at least some of the parts are off-the-shelf parts, which may be modified or simply incorporated into a new robot.

Further, the persons responsible for integrating different components may be distributed. A university might be developing vision systems, while a group of mechanical engineers build the frame, e.g. The fact that the design and development processes are often distributed among different persons, phases, and locations is not only crucial for the underlying design thinking and practices (and hence the successful completion of the projects), but also the approach taken towards ethics and responsibility in robotics.

As discussed in *section 2.3.3*, a company has built a cleaning robot for the hotel industry, as part of a public-private partnership to solve hotel staffing issues. As explained by the robot makers involved in the project, the process of design and development of the robot was distributed among different people participating at different stages. This was dictated by different funding rounds as well as the fact that the entire process took several years. One of the robot makers, who joined the project at a later stage, knew little about the origin and history of the project, but knew much about the development from the initial prototype to the market-ready product that he would continue to adapt. On the other hand, another robot maker was involved only in the beginning of the process in securing funding, and had very little to do with the technical development that followed. Therefore, just as it is the team that contributes to the robot design and development to a varying degree, it is necessary that different people, at different stages, are prepared to also consider ethical implications of their work. In other words, the entire team or group of collaborations shares responsibility for whatever unethical outcomes the robot's development might induce.

> *When you work in very small details in the development of a robot, you also know that you need a good, and a strong, and maybe also a decent-sized, team to create a robot that could actually have a harmful purpose. So, I don't imagine what happens in action movies that you have this one brilliant guy that creates something that could be really harmful. In my opinion, you need to have some kind of a team.*
>
> (Mathias, system integrator, robot developer, SPECTRUS)

Therefore, the initial selection of collaborators may make a difference in the possibility and timing of involving end-users (*see 5.0 Inclusive Design*), but responsibility for development across organizations and geographic regions makes it difficult to assign responsibility for user involvement (*see 4.0 Ethics Beyond Safety, section 4.3.1*). Another complicating factor of distribution is the distribution of development across time.

2.4.3 Technical beginnings (TRLs)

As participating robot developers have noted, users cannot be involved in the early stages of technological development, because the applications (and hence the relevant users) are not yet defined. Many publicly funded projects utilize technological readiness levels (TRLs) to measure the expected progress in a project. Most of the robot developers interviewed do not actually think about TRLs in practice, but TRLs do prove useful for the purpose of analysis.

TRL 1: basic principles observed
TRL 2: technology concept formulated
TRL 3: experimental proof of concept
TRL 4: technology validated in lab
TRL 5: technology validated in relevant environment
TRL 6: technology demonstrated in relevant environment
TRL 7: system prototype demonstration in operational environment
TRL 8: system complete and qualified
TRL 9: actual system proven in operational environment

From TRLs 0 to 3, robot developers are engaged in basic research, or 'invention', where the goal is to make a technological breakthrough that might be taken up in development. Innovation occurs between TRLs 4 and 9, where the initial invention is applied in a new way. It is during these stages that the application and environment is defined, which means there is an opportunity to identify potential end-users. Unfortunately, we find in REELER that few robots actually start from early-stage TRLs – or at least the idea is not always traceable.

The CUTS project is a perfect example of how a robot idea is formed and developed from familiar beginnings, by a group who have previously worked together on a similar project, and not from early TRLs. It involves both people from a technical university, a private company and some technical partners dispersed in different countries in and outside of Europe. After more than two decades of working on this kitchen robot in the company KIT (Kitchen Technology)[2], the main CEO acknowledges that the robot will not be ready for market. Following a recurring REELER finding, this robot company, does not begin by asking end-users, i.e. the people eventually supposed to work in kitchens with the robot, about their everyday practice. One of the reasons the group has taken so long to develop the robot is that they have only gradually learned about the motives of everyday people working in the application area, even while the developers' own motives have changed over two decades.

2 Some identifying details are altered to avoid violating confidentiality and ethical principles. References in the quotes are changed, but the quotes are taken from actual REELER-interviews.

STORY FROM THE FIELD:

On a design and development process

Motivated by passion

Beginning with their passion for robotics and their previous collaborations, a group of (male) robot developers decided to make a new robot. They had previously worked on a robotic device that they, as students, thought could help in the kitchen at their university. Hence, the idea of constructing a cooking aid robot for a kitchen environment began around 20 years ago with a basic concept of a cucumber-slicing kitchen robot.

One of the guys, Jannick, eventually became a CEO of the company they formed together. The robot they are developing today is a continuation of this early prototype. Paul explains about the prior cucumber project:

Then there was actually the very first robotic project which was carried out in the Uplands, and maybe also one of the first worldwide, on an autonomous cooking aid robot that could help slice cucumbers in the kitchen. This was a project financed by the Ministry of Innovation, because they said, or they could not believe, that it would be possible at all to develop an autonomous system that is able to pick up a cucumber or a fruit and slice it, when asked to. They said: "So okay, can you demonstrate that?" […] That is now seventeen years ago.
(Paul, CEO, robot developer, SANDY)

Motivated by research

The robotic team, working from a research-oriented approach, got public funding from the local government and managed to build an operational prototype kitchen robot for slicing cucumbers (though not finding and picking up cucumbers by itself). They were certain the robot could be used in private homes as well as in restaurants. However, at the time the market was not ready for this kind of robot, according to a roboticist colleague in KIT:

At that time, the restaurant owners were not asking to replace their labor yet, with robots. Maybe, this was the period at which we got a lot of Eastern European people coming from Eastern Europe to help in the restaurants. […] Restaurant owners move by economics. When they have problems with surviving and getting enough money earned, they see that labor is a problem now, so they start asking for this kind of thing.
(Michael, CUTS coordinator, robot maker, SANDY)

More than a decade after the first robot project, KIT became the research coordinator of a new robotic development project called CUTS (Clever Utensils). CUTS was a publicly funded international project answering a call for new production technologies including service robots. The CUTS project did not only focus on one specific task in the kitchen, but developed several technological demonstrators for high value tasks like slicing vegetables and fruits, and destemming grapes. However, one aim was to build a robotic kitchen prototype for handling mushrooms. A roboticist from KIT, who now work on COOK and who also previously worked in CUTS, explains the aim of CUTS project:

Paul: CUTS' idea was to build a modular robot system that can be reused for different applications. The applications in CUTS have been the slicing and peeling of different fruits and vegetables like apples, tomatoes, grapes, and precision cutting in a kitchen.

Interviewer: Okay, so it was meant to do different things?

Paul: The idea was to have, let's say, have the same robotic arm, and moreover the same software which is behind, because a lot of components are very similar. And then maybe have different kind of grippers for the different kind of tasks. That was the basic idea of CUTS. And what we finally did in KIT, was to focus on the handling of the mushrooms. That was our responsibility […]. In CUTS our partner for instance in Inland did the grippers for apples and grapes and our third partner in Outland did precision cutting equipment […]. So, there were more partners involved.
(Paul, CEO, robot developer, SANDY)

The CUTS project was accomplished four years later, at which stage the developers (an international group of more than 10 participants across 8 countries, mainly from Europe) had managed to build the first demonstrator of an autonomous kitchen robot. They had promised to reach TRL 9, to be able to make a kitchen aid robot demonstrated in an "operational environment".

The CUTS platform, however, only achieved a success rate of 9% for identifying fruits and vegetables and 33% when a colour scheme was added in the specific 'kitchen laboratory' built to test the robot. Several key research challenges therefore remained before widespread commercial adoption could occur. These design challenges had among other things to do with perception, motion planning and software and hardware design, the researchers in KIT decided.

Motivated by previous work

They therefore decided to continue building on their previous work and applied for another publicly funded project, COOK. The COOK project was intended to solve the remaining challenges of CUTS, and commenced five months after CUTS ended. *"It is the next phase actually,"* Jannick said. In this sense, the COOK project started with both a narrative success story of the ability of designing an operational kitchen robot for cucumbers 20 years earlier at KIT and a robotic prototype from CUTS. For this reason, COOK has never had Technical Readiness Level (TRL) of 0. Originally, the COOK project was meant to have a duration of 46 months but now only two months remain and they may apply for an extension, because the developers have not managed to reach their objective yet. According to one of the roboticists, the robot from CUTS ended with a TRL of 6 - 7, and COOK is today *"more or less still in this phase"* (Jacob, CUTS coordinator, robot maker, SANDY). In order to get COOK ready for the market (TRL 9), the project needs more time and economic founding, the CEO from KIT concludes.

Since the prototype from CUTS, the roboticists have made ongoing changes in the design of COOK in order to improve its functionality and speed in handling mushrooms:

In research, you always have a prototype, which is big and has a lot of possibilities, and once you know how it should operate you can cut off these possibilities, and bring it back to essential things. This is the design process.
(Michael, CUTS coordinator, robot maker, SANDY)

In our project, we defined that we would have a basic system and an advanced system. And we are somewhere in between the two at the moment. So, our basic system with the robot is here, we used it in our previous tests.
(Jacob, researcher, robot developer, SANDY)

The design process is both described as a way *"to simplify"* COOK from the prototype from CUTS as well as making the robot *"more advanced"*. The changes made relate to the sensors in the gripping system, camera, and cutting system. It was only when they began testing the robot in the laboratory kitchen with other people moving around it, they noticed how humans functioned in the kitchen. They continuously made the robot stop working by reaching in front of its camera or sensors. This acknowledgement only came in the last phases of COOK. This paved the way for new innovative solutions as to where to place sensors and camera – and Paul, the CEO of KIT, now realize that the robot in its present form will never move to restaurants or private kitchens. And that some things could have been easier if the development had begun with working together with kitchen staff and real cooks to get a sense of their real work routines.

At the time of our visit, the second version of the advanced COOK robot was being developed. The robot was not operational for tests at the time of REELER's fieldwork, due to trouble in the design process. The team of roboticists waited for equipment to be fixed before they could continue the robotic work:

One of the equipment to maneuver it was broken, so we ordered a new one. So, we cannot operate it at the moment. It's a little bit, uh, unfortunate right now. But we are in between phases, and we are now working on the second, advanced robot.
(Jacob, CUTS coordinator, robot developer, SANDY)

The redesign has entailed a step backwards in the robot's TRL:

Michael: It takes you a little back from where you where, but we try to leap beyond that by making things more advanced actually, and [by] having these things like artificial intelligence go in there to detect the soil on the mushrooms better, to be able to decide and control like people do. […]

Interviewer: Okay, so you are actually going a little bit back from this [CUTS] in readiness level, but you think that doing so, you will make it smarter in the end because you make it more advanced. Yes?

Michael: Yeah. Yeah, you have to mimic the human behaviour more and more.
(Michael, CUTS coordinator, robot maker, SANDY)

Thus, it is really difficult in non-linear development patterns to identify opportunities for starting with end-users. The kitchen robot began as a working prototype in an already defined setting, but ended in a different application and as a slightly less operational prototype.

(Based on interviews with Paul, robot developer, Michael, robot maker, and Jacob, robot maker, in the SANDY case.)

In at least two of the eleven case studies in REELER, the current robotics group was established on the basis of public funding for continued development of the same prototype. In both cases, the robot changed its name and a few specifications but the consortium was more or less the same. The main difference was in the scope of the projects. In one case, the first project would aim to help persons with bodily muscle impairment caused by genetic diseases. The second project would include a much broader group of patients that suffer from muscular impairment caused by more common factors such as traumatic injuries.

> *When conceiving this project, we took the value of technology developed in the previous project. But we also took basic information from the exploitation plan of that project, which was the idea that in order to become a commercial product, any system of this level of complexity requires a wide market. (...) A huge difference was that before it was dedicated to very serious but very rare pathologies. (...) This led us to changing many aspects of the project. And this is how we started conceiving the idea of the project we are working on now. (...) Everything has started from there, the entire idea of the project, including consortium members.*
>
> (Luca, physiotherapist, robot maker, REGAIN)

Another example of a publicly funded project that builds upon previous work is an autonomous agricultural robot. The very first idea for the robot emerged from previous robotic developments undertaken at a research institute. Fifteen years prior to the current project, that institute was involved in the development of a similar harvesting robot.

> *This was actually, I believe, one of the first robotic projects in this area on autonomous fruit harvesting robots. [...] That is now fifteen years ago*
>
> (Espen, senior scientist, robot developer, SANDY)

These robot makers managed to successfully develop an operational version of a fruit harvesting robot. However, at the time the robot remained a research platform as the market was not ready for this kind of robots and there was no demand on the farmers side. The lacking demand well-illustrates the fact that being driven by the technology (or funding opportunities) instead of being end-user oriented in the very early TRLs, robotic projects may sometimes develop solutions that do not meet the actual robot users' needs. In fact, in several of our cases we see the robots were never at Technical Readiness Level (TRL) 0, 1, 2, 3 or 4. These design phases, were dealt with in connection with the previous robot worked on by the robot making teams and presumably not revisited. Thus, some developers may cycle around the same robot project, because they have not reached what was promised, and instead they seek funding for further development for several years in a row. We do not see this in the same way in companies which are more wont to move on to another type of robot.

REELER identifies two main risks following from this 'approach'. One is a research logic that does not emphasize the need for innovative robots to ever enter the market to contribute to solve the problems intended and to economic growth. The other is the risk of staying within only a narrow area of knowledge and networks of collaborations, with the main focus on technology rather than end-users and their needs. While such an approach may work well for robot makers, it may not necessarily be the case for end-users, who for long periods of time remain largely distant or excluded from the conceptualization and development process of the robot. Even from a design perspective, it can be a waste of time and money if the envisioned users are not included early on to avoid misconceptions and normative thinking about the users. However, from a robot maker point of view, it can be very difficult to know how to best involve users, because direct users and affected stakeholders are different and have different motives (which is why alignment experts are needed (*see 12.0 Human Proximity*).

> *It was not like the same people involved in the same project from start to end. It was different kind of cleaning assistants, different kind of IT nurses and so on, so that was not ideal. It is something that we really try to do now in the projects that we are doing, that we set this project team, also from the partner's side to make sure that they are committed and they are the right people that we have involved in the project.*
>
> (Samuel, product innovation manager, robot maker, SPECTRUS)

It is a lot of work for robot makers to involve users directly. The robot makers are often looking for consistent users that can over time align themselves with the development. When users are coming with new motives, developers spend time again on buy-in and bringing them on board.

Interviewer: And why is it so important that they are the same people?

Samuel: I think it's also something like satisfaction for them that they see that the value of their input and insights is something we actually use eventually. It's not something that they just have to participate in in a two-hour meeting and they don't hear anything about the project until maybe there's a product in three years. So, I think it's good for them and it sort of motivates them a bit more to be more involved in this process I think. So, I think it's good for them, but of course it's also good for us because then we have sources on all our data fragments from the projects and who gave that knowledge and then we can call that person again and ask again and they are well informed about the project and it saves time also for us, I think. So, it's just a matter of finding the right people and that's always a bit of a challenge, I think, for us.

(Samuel, product innovation manager, robot maker, SPECTRUS)

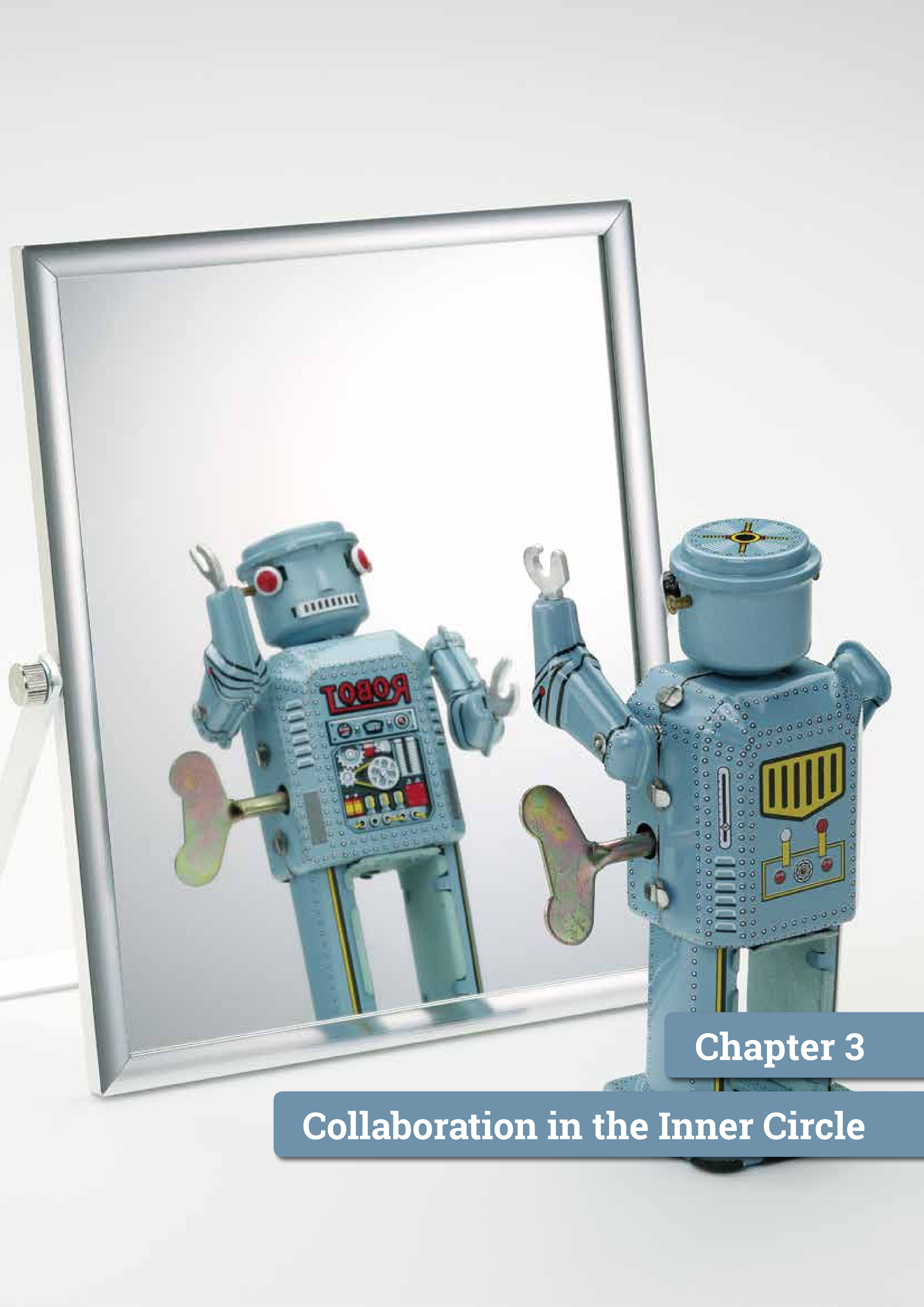
Many of the robots developed in customer-oriented design processes are created in areas where the developers may have little expertise and knowledge about the application's situated context. This entails a lot of collaboration in order to identify market opportunities – and in some cases user-needs and reactions to their robot ideas. However, in all REELER cases, the beginnings of new robot solutions are initiated by robot makers (robot developers, funding bodies, or robot buyers acting as application experts), and not by the potential end-users or affected stakeholders. While end-users who lack expertise in robotics cannot be expected to define the solution, they ought to be considered in defining the problem; however, as it stands, end-users' needs are brokered by intermediaries. Put differently, robot beginnings occur within the inner circle – the 'robotic bubble' of REELER's human proximity model (*see 1.0 Introduction and 12.0 Human Proximity*).

Clients or customers (like the director of a public hospital, a farming company, or a public transport company) may wish for specific robots and act as facilitators with the robot developers and in some cases application experts. Yet, the end-users and affected stakeholders, i.e. the people working in farming, hospitals and public transport, are generally involved only to test already developed ideas. Many affected stakeholders have very little knowledge of robots and what they can do for them, if developers were to communicate with them the potential of robotics, many stakeholders could (and have) come up with good ideas based on their expertise in their daily work. One example of this is a cleaning lady in Portugal, who suggested a robotic arm to remove the spider webs she cannot reach on her own (*see 11.0 Gender Matters*).

Another has an idea for a robot that can easily move a bed so she can clean beneath it without straining her back. A worker in a construction site would like a robot that helps speed up, not slow down, work. However, the question is not only whether a given robotics project start with end-users or is user-oriented, but also the priority given to end-users and their well-being (as opposed to the mere purchasing power). Across cases, we see this as an untapped resource for novel ideas in robotics that are well-defined in relation to the application area. Unless familiar technical beginnings and existing homogeneous networks are opened to affected stakeholders and their experiences, these resources may remain underutilized.

2.5 Concluding remarks on Robot Beginnings

Familiar beginnings breed familiar results. To truly be innovative requires heterogeneity and novel ideas. Where public funding is involved (in most cases), the return on investment must be fairly distributed. Design processes should thus be more inclusive, taking in persons with diverse motives. By bringing end-users and other affected stakeholders into closer proximity to robot makers – by expanding the interaction space (puncturing the robotic bubble), it might be possible to bring about some alignment between them. User involvement in robot beginnings is further hindered by robot developers taking their starting point in familiar people and existing technologies. This is complicated, however, by the distributed nature of robot development, both in terms of time and geography, but also in responsibility across organizations. Ultimately, if organizations are so motivated by making money as we argue in this chapter, it might behoove them to solve these problems of engagement with users, so that robot developers can go on pursuing their passions for robotics and doing good.



Chapter 3

Collaboration in the Inner Circle

I don't know if that's a typical day really, but perhaps the other thing I should say is, that [our CEO], is going to be at our prime minister's office in a couple of hours' time. So, they're hosting a reception for the tech sector to kind of acknowledge the tech sector's contribution to society and the economy. We are going to be there with a bunch of other AI related startups as well. So, yeah.

(Bran, robot developer, engineer, HERBIE)

◀ Robot developers are often engaged in collaborations with like-minded people.

3. Collaboration in the Inner Circle

You will find here

- An overview of actors involved in existing collaborations with robot developers
- A disambiguation of the term end-user
- Descriptions of different collaboration types and reasons for collaboration within the inner circle of robotics
- An analysis of the gap in collaboration between robot developers and affected stakeholders
- A discussion of potential collaborations with social scientists as intermediaries

You will acquire

- Awareness of who collaborates with whom in robotics and what each stands to gain from these collaborations
- Awareness of the consequences of sidelining or excluding end-users from collaborations
- Awareness of the potential benefits of collaborations with social scientists who are trained to bring affected stakeholder voices into development

In this chapter we take a closer look at the collaborations between the robot developers who enable robots in technical collaborations (primarily engineers) and other robot makers, including other robot developers, application experts (e.g. robot buyers and psychologists), and facilitators (e.g. policy makers or financial contributors). We will examine the gaps arising when end-users and other affected stakeholders are not understood as the people who will eventually be affected by robots. In the subsequent chapters we unfold the consequences of these gaps (e.g. for inclusive design, work, and gender issues). Here, we focus on the robot makers as the key target group of REELER's research, their collaborative learning, and the alignment of motives within three main groupings: among developers themselves, between developers and application experts, and between developers and facilitators (especially funding agencies).

Networks are formed between these groups at for instance conferences, fairs, and seminars. Many times, the people involved in robot development build on previous collaborations and connections to particular funding agencies and application experts. However, REELER has also identified two groups that robot makers do not meet so often and rarely directly *collaborate* with. These are the affected stakeholders and social scientists who could bring new knowledge of the everyday life situations robots will be affecting. We have, as mentioned in the introduction (*see 1.0 Introduction*), seen that end-users form an interesting category as they can be understood in two ways. One understanding of 'end-users' is the same as we have defined in the REELER project: the persons who might actually *use* the robots. However, in several REELER cases, robot makers talk about end-users as the people who *buy* or *invest* in the robots. These persons who act as *spokespersons* are sometimes the closest the robot developers get to actual end-users. Thus, they often only discover very late in the design process how the actual users on the shop floor with hands-on experiences of every day work will be affected by their robots.

In REELER's analysis for this chapter, we begin by acknowledging that the collaborative learning sought after is expected to take place *between very different* groups. On the one hand, the people who enable, design, make, develop and implement robots: 'robot makers'. On the other hand, the various people whose work or lives are affected by robots, whom we term 'affected stakeholders'. What separates the two groups in our

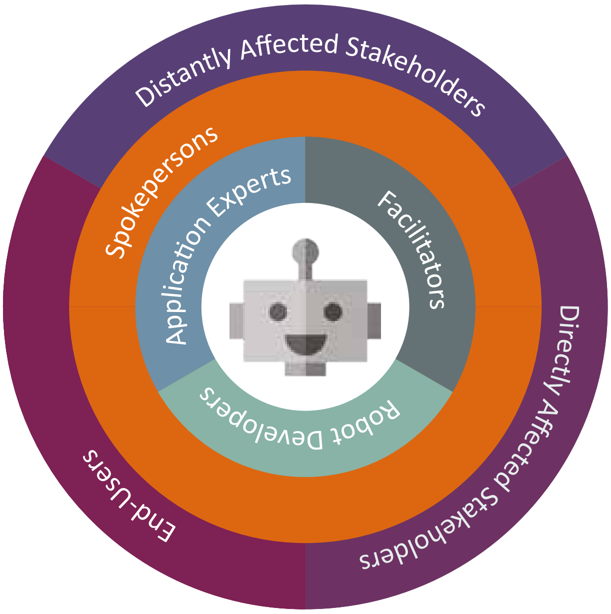


Figure 3.1: Collaboration with spokespersons (e.g., company owners) is often the closest robot developers get to actual end-user collaboration.

analysis is that the robot makers (which include powerful investors) consistently collaborate and learn from each other, whereas the people in the second group, the affected stakeholders are not directly included as *collaboration partners* in any of our 11 case studies (but may be used as test persons or included in decision making as in our two best-case scenarios). It is perfectly natural and logical that we stick to learning and collaborating with people we already know. As already noted (*see 1.0 Introduction*), from an anthropological point of view it is a common thing for humans to form normative bubbles where they feel at home with like-minded people. However, throughout this publication, the REELER material shows that the robot makers have something to gain by leaving the inner circle of robotics.

This chapter has six main sections identifying present day collaborations:

1. An overview of the actors involved in present-day collaborations as they have emerged in our ethnographic research.
2. A description of the technical collaborations between robot developers.
3. A description of the collaborations between robot developers and application experts. (It may be a robot buyer who functions both as application expert and as a 'spokesperson' for the end-users.)
4. A description of robot developers' collaborations with facilitators, like funding agencies, policy makers, and robot buyers, all of whom may act as funding facilitators – but also other 'helpers' such as lawyers and media people in PR and marketing.
5. A discussion of the identified 'gap' in collaboration between robot developers and end-users, directly- and distantly affected stakeholders (who may be otherwise represented by 'spokespersons').
6. A discussion on robot developers' lack of collaboration with social scientists as intermediaries (instead relying on robot buyers as 'spokespersons').
7. A discussion of the problems arising when robot developers try to leave the 'bubble'.

3.1 Overview of collaborators

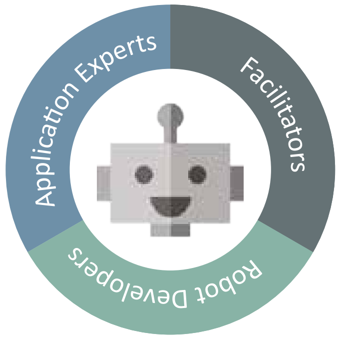


Figure 3.2: Inner circle of robot makers

REELER research shows that robot makers have plenty of experience with collaborative learning. In fact, the field of robotics is already filled with interdisciplinary collaborations. REELER's Human Proximity Model (*see Introduction 1.0*) has an 'inner circle' around the robot, persons we collectively call *robot makers* (*see Figure 3.2*). The people found in this 'bubble' around the robot are the people we have identified as those who collaborate, learn from each other, and share motives around the enabling of the actual robotic machines: *developers* (mostly engineers), *facilitators* (for instance funding agencies, buyers of robots, and politicians) and *application experts* (people called in to help with the robot's specialized tasks, like a medical devices company explaining how existing physical aids are used for manually turning patients in the bed).

It is a finding across REELER's cases that no matter what type of robot we have looked at in our empirical research there is close collaboration among the people in the inner circle who meet each other on a regular basis at robot fairs, conferences and events. REELER data also shows that the persons who are going to operate the robot, work next to it, or who will be otherwise affected by it, rarely take part in these collaborations. They are not considered application experts, who can give advice whether a robot should be developed at all, or how and where to implement robots. Knowledge about people (e.g., on the shop floor for industrial robots) is developed in the robot projects when robots are tested on end-users and for most of the time these tests take place in laboratories and thus in environments far from the confusing and complex everyday life, where the robots eventually are meant to be implemented.

Furthermore, not least in robot projects receiving public funding from EU but also on national levels, there can also be close connections between developers, financing agencies and policy makers. The robot developers, i.e. the people with the technical expertise, can be CEOs and/or owner of companies or take up other managerial functions with the role to develop whole robots or parts of robots. They often work in close proximity to and collaborate with the robot facilitators. Facilitators are not just politicians and funding agencies, but also people hired by a robot company to help facilitate the uptake of robots through media imagery (*see 8.0 Imaginaries*), or lawyers who help with legal issues. Robot developers, especially CEO's, develop good skills in collaborating closely with the funding agencies facilitating robots through for instance EU-financed funding, national funds and private funds. These funding agencies, REELER's data shows, often play an important part in the lives and work of the robot developers and thus have a lot of ethical responsibility for what kinds of robots are developed. The European Commission funding schemes we looked at never explicitly called for a direct collaboration with end-users and/or affected stakeholders – and it is by some considered a bad idea to involve end-users and other affected stakeholders in the early design phases, as it may hamper innovation.[1]

However, close collaboration between the robot makers without collaboration with affected stakeholders creates a gap in the common knowledge and common language (*see Introduction 1.0*) between those who collaborate to create the robot and the knowledge of those who will be affected by the robots in their daily lives. Though end-users are included in design processes it is primarily as test persons late in the design processes. REELER has several examples where robots are developed in close collaboration with end users (understood as users not application experts) at the later stages of design work – and where all kinds of new and unforeseen issues come up when the robots are tested (e.g. ATOM, REGAIN SPECTRUS, WIPER and OTTO). In other cases, the end-users are assumed to be, for instance, 'normal workers' (*see 5.0 Inclusive Design*) and in most cases the directly affected stakeholders are overlooked in design processes. Even when robot developers go through a lot of trouble to identify the right end-users, the complex richness of the everyday life situations are overwhelming when robots are eventually implemented in real life situations (*see 7.0 Learning in Practice)*. The directly affected stakeholders, the nurses or physiotherapists close to patients, or teachers close to children, can be drawn into projects to give advice (as in the above mentioned cases), but in general neither the directly affected stakeholders, nor the end-users, are seen as the people with important expertise in the application area or sector particular to the robot under development. This role is left to the buyers of robots, often considered the actual 'end-users' by robot makers (*see 1.0 Introduction*).

The reason this 'gap' is a problem is because of the closed nature of the culture in the robotic bubble. Each of us is equipped, by our experiences, with particular tools for engaging with the world; when people have a shared set of tools, we call this culture. What we find is that persons within the robotic bubble are often working from a shared set of experiences. In spite of diversity in for instance education (engineers, economists, lawyers) found within the culture of collaborators, it is easy to see, for instance at fairs and conferences, that there are also huge similarities within the group. Most are male, white and between 30-50 years of age. They have a higher education, good salaries, and work prospects in the future and aligned motives for creating new robots. All of this create good conditions for collaboration based on a common knowledge and language (in spite of possible internal disagreements). In this respect they may differ substantially from most of the stakeholders who eventually will be affected by the robots in *their* everyday lives. These stakeholders are a diverse group with no common language around robotics and no relatively aligned motives that bind them together. They are, as we show many places in this publication, often without higher education, they may fear losing their jobs and also have little knowledge about the robots that will affect their lives.

3.2 Technical collaboration with other robot developers

In their daily work, robot developers first of all collaborate with other robot developers (within their own spheres of interest and type of robots). It can be software engineers working with hardware engineers for instance. It is in this inner circle closest to the actual design of the robot that we find a common (technical) language and common motives of developing robots. Robot developers share with each other the goal to design robots, and they share a technical language of how to do it. In many cases the robots develop out of a small group of (male) colleagues who work closely together.

The engineers working in different companies may be competitors, but they understand each other's motives for competing. They may disagree on issues but basically, they work towards the same goals. They share an understanding of what robots are really like; that is as machines instead of the media representations of robots (*see 8.0 Imaginaries*) and all the problems tied to making machinery work. Where the general public see the autonomous and humanoid robot shell the engineers see all kinds of wires, connectors and software.

1 We are fully aware that not everyone believes that it is good for an innovation to begin with close collaboration with the end-users and affected stakeholders, and this is discussed in many places in REELER's material (see for instance the chapter on Innovation Economy). We are pointing out that our empirical data shows that projects beginning with end-user collaboration are uncommon, and that this might affect how robots can be made responsibly and ethically. We could also argue that we may find an untapped source for innovation if robot development processes began in collaboration with end-users and directly affected stakeholders.

> *Robots typically are something that attracts most of the attention and then who cares about the rest because the rest, like software, there is nothing really to see. But in reality, just for you to understand, robots are just the tip of the iceberg and then there is software and there are other elements that make together the system, the solution that will deliver value.*
>
> (Felix, robot developer, CEO, WAREHOUSE)

Robot developers invite other professionals into a collaboration of solving ongoing specific problems. The collaborations can be face-to-face working with technical people or other people from disciplines with doctors or psychologists in relation to specific projects or social media.

Robot developers across cases like for instance Franco (BUDDY), Toby (COBOT) and Jørgen (WIPER) participate in collaborative technical platforms like ROS or with robotic hubs to solve specific problems. ROS stand for Robot Operative Systems as a common denominator for software libraries, standards and protocols that help develop robotic applications.

> *And it's [like] everything is in ROS so for us that's very easy to start. So, that's also the reason why in just two months with mainly seven people we did a lot of work.*
>
> (Franco robot developer, BUDDY)

They visit each other – even physically to collaborate on technical issues.

> *We had a couple of people that we had close links with, a couple of machine fitters, also from the robotic hub, that we were in close contact with, and if we had some questions, then we called those people and said, 'we have something we want to show you. Can you come by?' And then we just arranged [it], well, perhaps Wednesday was good, and then they came by and then we showed them what we had made, and then, is that good or bad or what do you think? Then we got some feedback and then we noted what [we could use their comments for]…what part of this is just complaints and what is something that we can actually change?*
>
> (Jørgen, robot developer, WIPER)

Toby is also working on a humanoid robot in close dialogue with colleagues and tells us he often contributes to ROS with new solutions and also gain from his colleagues' contributions to ROS.

In these collaborations the technical developments are the pivotal point for robot development – and this means that technological considerations may overshadow user considerations. Not least because as the technology is the main focus, it is often unclear who the users really are.

Thomas, a robot developer, for instance work with software developers and hardware engineers as well as with a team he names 'user experience people'. They turn out to be mainly design experts who give advice about how the robot should look. Even if he sees the need for collaboration with end-users, the users are brought into his project as test persons. This is also because Thomas and his team, like many other robot developers (see Leeson 2017, Bruun et al. 2015, Blond 2019) begin with the technology – and only gradually finds out how the developed technology can be useful. Here the same technology is attempted to be useful for very different users from nurses to shop assistants.

> *Interviewer: Is the robot now ready for market?*
>
> *Thomas: That's a, that's a big question. Because you have on the one side, the user experience. You have on the other hand, all the applications. And you have the technical point of view. From the technical point of view, I would say we have lots to do. Because we want to get in production. We need to reduce the costs, that's one of the main points why service robots are not running around everywhere, I think. Yeah, from the user experience, we also still have some things left. We have an industrial version, with just a mobile base with a manipulator on top of it, it's the same technology. And we're also working on some kind of medical devices, so we developed a robot that is meant to be helping people learning walking again after a heart attack -so it's the same technology. We have four wheels, a battery, and our vision around it.*
>
> (Thomas, engineer working on a humanoid robot, COBOT)

Later he explains to us, that they also consider it for customer experiences in warehouses.

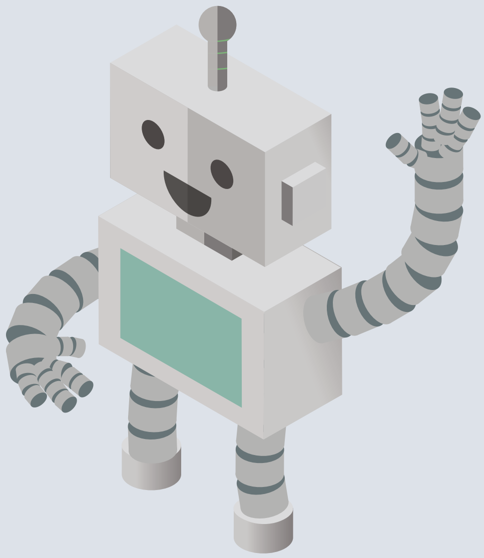
Thus, he only meets the users' everyday lives when he begins to implement the robot in different places and get responses from different users to a technology already developed.

In the REELER data this multipurpose approach to robot design, starting with an available technology, is not uncommon. You begin a collaboration with technical people, then the facilitators securing funding and then much later the developers draw in spokespersons and application experts representing the humans supposed to benefit from the robot.

STORY FROM THE FIELD:

On the process of developing robots in a social group exploring technology

In this story we follow the process of developing a storage robot, STOREX, from the perspective of a group of Eastern European robot developers.



Felix explains how it began as a group of three friends creating a start-up almost as a hobby (also seen in the ATOM case). He joined the group later, but back then the group collaborated with each other without any office or laboratory equipment – and reach out to the technological robotic community to take a closer look at available technologies. They got hold of an advanced robot and scrutinized how it was made.

Felix: So how things started, basically, in 2013 – and again, Anders, who is the CEO, will tell you a little bit more of the history – it all started back in [Easter European country]. So, the people back then were working on the very early prototype. So, most of the start-up started in [this way]. This was not yet in the garage, it was in the apartment, and that was just the idea. Okay, we saw [available transport] robots, and [these robots] were acquired by [a large company] so they're no longer available, and the guys were trying to test and see if it's difficult to make this kind of robot. What does it take to produce this?

This was neither industrial research or university research, but as Felix puts it:

It was probably a hobby. Let's put it this way. (…) It started with people in their own spare time. Again, it was in the apartment and then it moved down to the garage because the robot got bigger. So, by any means, it's not industrial [research]. Really, it's more like a kit made of the components available on the market. But even to understand how you control it, how it moves, what it takes to carry a rack, because you'll see the system is actually about bringing racks to people and racks carrying goods, so this is where it started and this was back in [the Eastern European country].

The idea was to try and see how difficult it is [to make] because, when you look at it, it looks simple. Okay, a robot, you see many great things when we watch science fiction videos, but in reality, the [guys back then] were trying to understand what does it take to create something like this. So, the point was you can call it research but it was more like a hobby at this stage.

So, the guys realised – and it was a team of three people at the time – yeah, we can make it work. That was the first conclusion. The second was, yeah, if we can make it work, then we have to actually make it more than just a hobby. Then it becomes part of the foundation of a start-up or foundation of the business. So, then the company actually was created in [a Western European country].

Only then they began the next step in collaboration, namely to seek funding opportunities, which they found. Only much later in the process were the end-users supposed to engage with the robot involved.

(Based on interview with Felix, robot developer, CEO, WAREHOUSE)

3.3 Collaboration with application experts

Robot developers, or their companies, collaborate with others outside of robotics to explore new ways of technical development– often either driven by or in connection to universities and especially new applications for technology already made. Application experts are in our general definition the people who have an expertise in the areas where the robot is supposed to be applied (*see 1.0 Introduction*). As these areas differ, so do the application experts, but across cases we see that robot developers make a lot of efforts to collaborate with and learn from these experts. They can be psychologists giving advice to engineers on how to design robots so they are not scary or a university expert on farming giving advice on what crops robots are needed for. The way the robot companies define the *experts* called in to help develop robots with the engineers are rarely the people affected (directly or indirectly) by robots in everyday life though they can be called in as end-users to test results. However, sometimes the owners who have power enough to order and eventually buy specific robots are speaking on behalf of the actual end-users.

> *Do you know what, I spoke to a lot of professional workers and shopping mall management companies. For instance, in [my residence country] I had a chat with companies [retailers] or for instance with [a retail company], they own a lot of shopping malls, both of them roughly best forty shopping malls across the [country]. And they became interested and engaged with the idea.*
>
> (Guy, robot developer, WAREHOUSE)

Across our REELER cases, we find that big farm owners, contractors, dairy owners, industrial company owners etc. often represent and speak on behalf of the actual end-users. Robot developers may also, for instance, reach out to communities like hospitals to explore potentials for robot developments. Often but not always universities are involved in collaborations. In these cases, the point of departure for a collaboration is not a problem-space defined by the end-users and affected stakeholders, but often a question of finding expert advice on where to apply an existing robot technology so it becomes helpful in a particular area. This may allow the same technology, with advice from different experts in different application areas, to move from one kind of application to another. We have for instance seen a space type robot become a healthcare robot or an educational robot. Applications of an existing technology can, with the help of application experts, move a robot developed out of shear curiosity and passion into an area where it can find a use, for instance in 'education'. Here new application experts may open for further applications, which then lead to adjustments in the original machinery.

> *They ran a preliminary study and they decided that robotics could be interesting. From that point we start to explore where we were able to apply robotics. At that time, I was doing some studies only related to education and with educational robotics, and then we identified that that technology could apply a lot with children with autism. We started to explore this with the hospital, but after a few months we got the project (funding related to social robots) and an educational robot platform to help children with traumatic brain injury. And like it's how we start this relation, and that was seven years ago.*
>
> (Pedro, robot developer, BUDDY)

However, some robot types are very specialised, e.g. in agriculture, and need application expertise tied to a particular field. Sometimes the robot developers in our REELER cases have collaborated for a long time with the same application experts on the same technology across several projects (e.g. OTTO, REGAIN, SANDY). These collaborations can involve company owners, hospital management, big farm owners as application experts. At other times the robot developers call in application experts from other areas when needed in specific situations. For instance, school teachers, psychologists, medical doctors and physiotherapists are called in to help adjust the design.

However, sometimes application of an existing robot technology takes place because an application expert and a robot designer simply meet and begin talking to each other in an inner circle collaboration (as has also been show in research outside of REELER, e.g. Hasse 2015a).

> *I was involved in research, that's market-close research, ok? Which means I was always very close with the industries, ok? And then, because I worked in the intelligent systems as in the data-processing, data scientist, and robotics. Now, robotics, everything about data-processing, making effective decisions, ok? So, it was quite an accident, I met [xx] that was interested [in my work]. [Following this meeting] they were interested in me come to help developing some intelligent system for them in robotics. Let me say, autonomous robotics.*
>
> (Ali, robot developer, CEO, WAREHOUSE)

Robot developers collaborate with other robot makers in the 'robotic bubble', reading the same literature, attending the same types of conferences, and thus aligning themselves within a shared culture.

3.4 Collaboration with facilitators

To realize the goals/ideas, the robot makers often collaborate with and learn from persons who can ensure funding. This means collaborating with funding agencies, potential buyers and engaged politicians, and it also implies hiring people to help protect and facilitate the uptake of robots. These can be media people, lawyers who protect the interests of robot companies and help make applications, funding agencies, investors, policy makers, national governments, and municipalities. Especially the funding agencies in EU are big players, and some smaller robot companies may feel the pressure, because they are not so visible and powerful in the inner circle. Here lawyers have found a good business as facilitators, that help 'read' the motives of the funding agencies and help with collaborations.

I think we can have some nice opportunities, because the European government provides a lot of money in case of European projects. The only problem is that these kinds of projects, ten years ago were really easy to access. Now it has become a business, so now there are persons – lawyers really – that just do this job; to support a big company to achieve the money, to take the money from the European project. And so, the small company does not really have the opportunity to have the kind of economical support.

(Alessio, Start-up CEO, robot developer, COOP)

Here especially EU's program officers, fund raisers, as well as selected partners are important collaborators expected to yield access to funding.

In fact, getting funding (especially for universities or research institutes) or earning money (private companies) looms so large that it may overshadow getting the right people for the job – as long as they can live up to funding criteria. The funding agencies meet with the robot makers (mostly the technically oriented people) at a number of conferences and meetings, which REELER researchers have also visited. At these conferences and fairs the robot buyers and robot developers not only learn from each other. People from policy and funding agencies are also present. They talk to and learn from the robot developers and the robot developers in their turn learn what motivates the funding agencies and policymakers. Robot developers generally respond when funding agencies place new demands. They also listen to robot buyers. They use a lot of effort and time to align their motives with those of funding agencies and customers – and they often meet physically to discuss details. The 'problem space' to work on is defined in close collaboration between robot makers. EU also create an environment of cross-country collaborations in order to get funding and politics – however these collaborations can be difficult even considering the common language in the inner circle.

Robot developers and their companies also meet and collaborate with policymakers in order to define and keep in line with societal standards – especially EU (ethical) standards. It is in this last category we find more social science-oriented disciplines visiting the 'inner circle' – for instance people from psychology, medicine and biology, but especially philosophers specialised in robo-ethics (*see 4.0 Ethics Beyond Safety*).

In the REELER data we did not select the cases from who participates in specific robot competition, conferences and receive particular funding, but we see that in all cases funding is a big issue for the robot makers and that conferences, competition and fairs are important to keep up with funding possibilities.[2] At these fairs and conferences robot makers from the inner circle meet and debate their common goals – as we also see in most other areas of technology development.

> *On the one hand, such competitions are such a time sink, because you have to prepare for this contest, you have to write an application, you have to take part in it all. If these are nationwide competitions, then in most cases you have to go somewhere in our country. But the undoubted advantage of this kind of competitions is that in many competitions there are media that try to look for more interesting projects, especially those that win, and this results in the greater solution promotion in the media, ranging from local to nationwide. So, it largely allowed us to build this recognizable brand when it comes to our country.*
>
> (Dominik, robot developer, ATOM)

Apart from the collaborations with other technical people and funding agencies we also find, across almost all cases, that robot makers (or their companies) work in close collaboration with media people as facilitating experts – and here video production of well-functioning robots loom especially large (*see 8.0 Imaginaries*). It came as a surprise to the REELER researchers that robot developer across most cases have such a close collaboration with media people and that their public image matters so much to them, whether they are university based or based in smaller or bigger private companies.

Across many REELER cases the robot companies we study invest a lot of time and money in developing promotion for their robots and ideas through media. There are whole studios specialised in developing media material for the promotion of robots to the public or potential buyers.

> *Yeah [I work], with social media and social relationships of the company with other companies. And then I am the link between the client and the artist.*
>
> (Sam, robot developer and media facilitator, BUDDY)

These facilitators reach out to others in media networks, face-to-face in fairs, competitions and exhibitions or through social media like LinkedIn and Facebook in order to promote and enhance their business. For this reason, they also take part in exhibitions (where social scientists also sometimes contribute), competitions and fairs.

3.5 Gap in collaboration with affected stakeholders

Robot makers like the above meet, work together with each other and learn from them, and share motives. In all REELER cases, they do involve users to some extent in the design phases but often in a somewhat instrumental way to test equipment. It is here they discover they have designed for particular users with specific body-sizes for instance (*see 5.0 Inclusive Design*).

In terms of power relations, however, it is the robot makers at the inner circle who decide in the end. The users of robots, and sometimes even the directly affected stakeholders, do teach the robot makers a lot but not as *collaborative* partners. Their voices are not heard in relation to what kind of robots to fund and why. End-users often come into the robot makers' space when they have already defined a 'problem space', or found an application for a technology – and developed it, and now need to test it. Robot makers, and especially the engineers, can come close to the users' everyday lives when they test their robots, and they do listen to what they answer when users answer to the specific questions asked– but both questions and robots are defined by the robot makers.

Across case we find robot makers who work in close relation with what they explain to us are end-users in a specified field (construction, warehouse robots, agriculture, health). However, at a closer look the collaboration is with what we name 'spokespersons' such as a manager speaking on behalf of his workers, a farmer speaking on behalf of fruit pickers, a doctor speaking on behalf of patients. Though some reach out to communities outside the robotic 'bubble' or inner circle, it is

2 As it also is for many social scientists and university-based research.

Many affected stakeholders are overlooked in design decision-making processes.

often to find new applications (with adjustments) for existing technologies.

This kind of contact may result in new robots, but sometimes these attempts to collaborate also fail. We have no examples where a robotics project began as collaboration between robot makers and direct end-users or affected stakeholders (e.g., the people who will actually use/work alongside the robot). What robot makers sometimes refer to as users, turn out to be customers (*see 1.0 Introduction*). We have examples in the REELER data where 'users' are only involved by representation, through their managers, employers, healthcare providers as spokespersons - or are simply absent as an identified group. End-users, as identified in most robotic projects as the persons actually working in close proximity to the robot, are used to test and improve the almost finished robots.

End-users are in REELER terms people working directly with the robot. Customers are people who buy and/or implement the robots made by robot makers, but they are rarely *end-users*. However, robot makers often equate customers with 'users' without taking into account they are not the end-users (going to use the robots or work alongside them).

Robot makers rarely collaborate with the direct users of robots like the person working with the robot at the factory, the worker at the farm, the patients who need the robot to receive training or clean a room. Even when they tell us they collaborate with end-users, in reality they work with 'spokespersons' speaking on behalf of end-users (e.g. doctors speak for patients, hospital or hotel managers speak for cleaning staff). These persons have great expertise in their core discipline, but does not necessarily know what it is like to be a patient, a hotel cleaner or a factory worker. Robot makers meet some end-users when they are involved in testing, e.g., but it is not a collaboration so much as 'using users' to adjust the robot. Citizens, patients and other end-users are involved, but not as true collaboration partners, but only to test selected aspects of what it is like to be in physical proximity of the robot. These 'end-users' involved in testing are furthermore often chosen or selected by the spokespersons as when a factory owner is a customer, that speaks on behalf of the workers and point out the workers who should test the robot. When a person outside the robot makers' community asks for a robotic solution, it is often a customer approaching to collaborate. This customer is never the end-user or an affected stakeholder. These customers may therefore not be able to explain how the robot will function in the reality of everyday life of affected stakeholders.

There is a group of great importance for the robot designers, which is most often overlooked. This group we have defined as persons who, on the site of implementation, are indispensable for how the robot functions also in relation to end-users even if they are not using the robot themselves: **directly affected stakeholders**. Once we discovered this group in our materials, many examples came up: the agriculture robot that has to be rigged and maintained and plugged in to work, the construction site robot that demand somebody clear its path across the construction site, the training robot for home use that is tested on a patient, but forget that it is the husband or wife who has to fetch the robot and rig it onto the patient's body, the nurse who has to make a new routine to avoid collisions with the hospital robot. All directly affected stakeholders are, as the word says, directly affected by robots – and necessary for their success. Yet, they are very often overlooked in the design process studied by REELER.

Finally, we have the **distantly affected stakeholders**. Robot makers in our research seldom try to envision how robots may affect people they do not know and have never met from the outer most distant circle – far from their own human proximity inner circle. Yet the reason we include distant affected stakeholders is because people may be affected by the robots designed, even if they are never near the robot. These people have no voice in how the designs and implementations should take form. They might be fruit pickers, nurses, shop-floor workers or cleaning ladies, or warehouse workers who get new tasks or where it is obvious they will need a new education once the robots take over (REELER researchers have met several of these distantly affected stakeholders, and their voices are heard throughout the chapters of this handbook. They differ for instance from the robot makers by having very little tradition for education and maybe also from difficulties reading). These people may need help to develop new skills to change a work situation (for instance in order to be end-users who collaborate directly with robots). As robots come out of the industrial cage into people's everyday lives, these distantly affected stakeholders are increasingly affected. However, we do not see these distantly affected stakeholders as an issue to be solved by the robot developers alone – and their overall situation is therefore debated in Part II of this publication where we address the more societal issues of robotization. Distantly affected stakeholders may, however, be affected even if they never see a robot. They may be a worker who find a new and more rewarding job, when a robot takes over his or her former tedious work. However, the inner circle of robot makers could still benefit from listening to these people with so much expertise in everyday life issues. They may even get new ideas for innovation (*see 6.0 Innovation Economics*). REELER research shows that even the most distant affected stakeholders have ideas and opinions about robots and their functionality. They do, however, seem notoriously difficult to incorporate into a circle of collaborations – due to, for instance, lack of knowledge about robots, language barriers, educational barriers, fears of job loss, etc.

Why is collaborative learning with all kinds of affected stakeholders a topic that has become important at this point in time in robotics design? One reason could have to do with the robots themselves. As robots are increasingly being integrated into people's everyday lives, it becomes a necessity that robot makers learn to collaborate with those humans who are supposed to let robots of all kinds engage with them in their daily activities. These spaces that previously were occupied by humans and simple machines, are now expected to include robots with artificial intelligence (AI), robots that transform work life and robots that transform human-human relationships. This means that robots are about to change existing workplace environments – often in ways not taken into consideration by the people who enable robots. At least it is the affected stakeholders we interview, who comment on why human-human collaborations cannot be replaced with human-robot 'collaborations' without a loss of social contact.[3]

> *It means a lot at work to talk to one another. It might be that they have some ideas, that they comfort you, or they have some experience. But with robots, no. There are no persons to talk to, and you shut yourself entirely off. You can no longer find solutions to problems, so, it becomes very, very difficult.*
>
> (Elif, cleaning person at a hospital, SPECTRUS)

3.6 Collaboration with social scientists as intermediaries

However, in REELER research we find a need for a more profound way to use social scientists – and those who have a core expertise in studying other people's everyday life in particular. The gap between the robot makers, *including* the spokespersons, and the affected stakeholders consists of a lack of knowledge about the everyday life, needs and values of the people on the shop floor. Where the spokesperson can be an intermediary who speaks on behalf of recipients, this 'speaking' is based on the spokesperson's own experiences, which often are more like the robot makers' reality than the reality of affected stakeholders. Spokespersons can for instance be management level in the same organization where we find the end-users (e.g., the factory owner speaking on behalf of the workers). In this section, we will therefore introduce a new type of intermediaries, we see as useful for both the robot developers, the robot facilitators and the application experts – as well as for affected stakeholders: namely the ***alignment experts***. They are intermediaries who have a core expertise in understanding both the values, needs and practices of affected stakeholders, and understand the economic and technical demands of the robot makers. This type of job function does not exist today, but we propose it to close the gab (*see 12.0 Human Proximity and 13.0 Conclusion*). The task of alignment experts is to work to align motives and values of robot makers and affected stakeholders, based on

3 In the REELER data material we draw conclusions on both what people tell us in the data material, but also from absences and silences. Furthermore, we also note difference through contrasting statements from affected stakeholders and robot makers (see Annex 1 on Methods and Methodology, and Hasse 2019, Hasse and Trentemøller 2009).

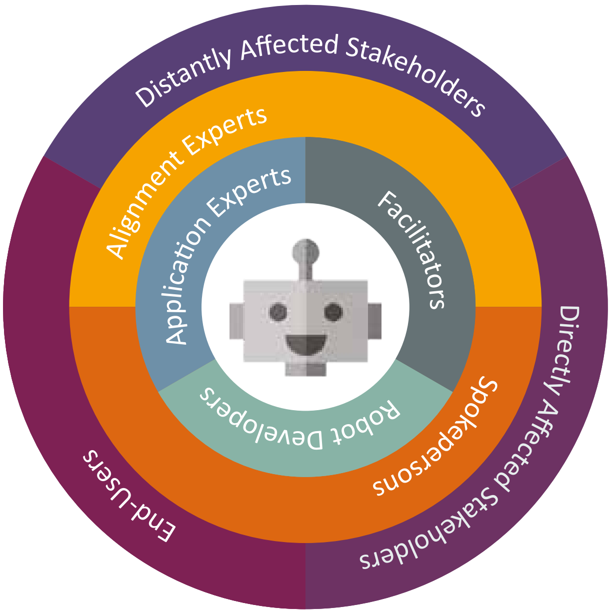


Figure 3.3. Alignment experts can be trained in the social sciences to better understand the needs and motives of both affected stakeholders and robot makers.

empirical knowledge of both. The alignment experts can have a core expertise in Social Sciences or Humanities (SSH) (e.g., an anthropologist or ethicist) but also need knowledge of technology and economy.

We do *not* think we as REELER researchers can live up to this description, yet also through our work we obtained close knowledge of both robot makers' practices and affected stakeholders' life-worlds. REELER researchers achieved some knowledge of the proximity gap and can see possibilities for potential alignment of their separate motives. To that end, REELER has developed and tested experimental tools for collaborative learning (*see the toolbox for engineers and other outreach activities at responsiblerobotic.eu*), which are designed to increase awareness of and attentiveness to other people's motives for collaborating toward a shared goal. Thus, the final Human Proximity Model is a prescriptive model consisting of three rings: the robot makers developing the robot, the affected stakeholders whose work and lives are changing as a result of the development, and the intermediaries who are tasked with translating the needs and values of the two other groups. The subsequent chapters all build on this model of human proximity, toward more responsible, ethical (*collaborative*) learning with robotics.

Why does REELER see it as a problem that robot developers only rarely use social scientists as intermediaries between affected stakeholders and themselves? After all, REELER research shows that robot developers are more than capable of getting knowledge of what users want through a number of other sources. Here is a robot developer pointing to a number of sources they use to get their knowledge of what users' needs are:

> *From client feedback. From fairs and events that we participate in. From feedback from our customer and from our customer department. So not just feedback from the people who bought the robot but what is people asking for when they are interested in our robots, what are they missing, what would they like to see, what is the main thing they are interested on, when they choose to buy a robot, why and what are this interest. As we mostly work with research centres. The other big part is just being quite up to date on the newest research that is being done. And with that we can get an idea of what the community is interested in, and with this we can decide what our next robots should have.*
>
> (Daniel, robot developer, BUDDY)

This is indeed an impressive list, and it covers most of the sources across cases, though each robot type also has their own special approach (not all work so much with research centres as BUDDY for instance). It also shows how much work robot developers need to put into robot facilitation. However, REELER also sees across cases robot makers are not including the people we define as affected stakeholders in collaboration, when the point is to get a thorough and holistic understanding of what matters to those who will be closest to the robots and will be affected in a positive or negative way.

This is also a novel way to make use of social scientists in the technical sciences. Today we do find social scientists involved in around half of REELER's cases, but they are not used to provide deep knowledge about the environments, values and needs of affected stakeholders.

Sometimes social scientists are involved in the role of consultants on markets.

> *So, we hired a couple of consultants last year and we did some due diligence on the market. There is a lot of information.*
>
> (Felix, Robot developer, Storex robot, WAREHOUSE)

In the inner circle of the Human Proximity Model (*see Introduction*), we find also collaborations with social scientists and humanists as they are sometimes brought in as application experts. They are often only loosely connected to the robotics work, but e.g. make surveys or give ethical advice as philosophers. In practice, however, if social scientists are involved, it is often limited to only brief meetings with external experts late in the design phases, typically with the goal to address already selected aspects of end-user needs. This may include hiring only single persons specialised in non-technical subjects (see story on collaboration with social scientists). This also means that social scientists are not involved as partners, but to provide the information that the robot makers have themselves decided is necessary as in the following case where social scientists were involved as the robot developers discovered that hospitals were complex working environments. The robot developers were very happy with the work done by the social scientist though they were never considered partners.

Interviewer: And did you collaborate with any social scientists during the process?

Samuel: No, I don't think so [as regular partners].

Interviewer: Do you have any among the staff?

Samuel: I don't think we had any external involved in that but we had some contacts where we sometimes I think ask them about related topics to social science and then, I don't remember specifically what we asked them about but they helped us and that was also their role. If the hospitals couldn't deliver the knowledge or insight we needed, then they would sort of help us by trying to get it from other sources.

Interviewer: And could you see any value collaborating with social scientists?

Samuel: Yeah, I mean we were a small team back then and definitely we could have used that perspective a bit more in the project, but it's difficult for me to say what it would have changed or what kind of impact it would have had. But I think, the role [the social scientist] had in the project was definitely something that contributed.

(Samuel, robot developer, SPECTRUS)

However, in some cases, we also find that the funding agencies prioritise projects with diversity – and that can help collaborations with social scientists. In the case of BUDDY there is a close collaboration with psychologists, but their work is still tied to the appearance of the robot and the like – and does not look into why affected stakeholder would need this robot.

We don't have social scientists in the company but in several of the European projects we are participating in, we do collaborate with experts in psychology, with social scientists and with other people from that part of the sciences.

(Robotics company, robot developer, BUDDY)

However, in general social scientists are not part of the inner circle and their potential contributions to robotics are largely unexplored. Sometimes the robot makers are simply unaware of this possibility of collaboration or see it as tied to 'basic research' and not to their type of work.

Interviewer: And do you also collaborate with social scientist or for example psychologist?

Alph: So, we do industrial application, we don't do deep science. So, we have very advanced applied research, but it's not science.

Interviewer: It's industrial development, not research?

Alph: Yes. It is applied. If you want it's applied science, but it's not fundamentally research.

Interviewer: But do you think it would be useful to collaborate with social scientists or it's not necessary?

Alph: Social scientists?

Interviewer: Like when you bring the robots—

Alph: What is that?

(Alph, Start-up, robot developer, WAREHOUSE)

In another interview 'social scientists' is simply understood as working with people from another discipline such as biology.

> *Interviewer: So, do you, (not necessarily just in this project, but in other projects), do you collaborate with social scientists or could you imagine yourself collaborating [with them]?*
>
> *Edgar: I mean, we haven't done it within the company but then in my previous lab when I was at university, we collaborated a lot with biologists. But specifically, I cannot imagine right now how to work with that person.*
>
> (Edgar, robot developer, SPECTRUS)

Sometimes the areas of expertise associated with social scientists may involve safety-related domains or any areas that involve non-engineering subjects and engagement of end-users. Also, social scientists are often viewed as persons who simply deal with the 'social' aspect of the design and use of robots. Such an approach does not allow fully exploring the benefits that would come from collaborations with social scientists and in a way that their contribution would actually inform the design process for the benefit of both affected stakeholders and robot makers if they were included in the collaborative learning in the early design phases.

Though some robot makers in the REELER data are more advanced in their collaborations with social scientists in attempts to reach out to other communities (e.g. hospitals), the focus is on collaboration between the public, industry (market) and university to implement, test or evolve the existing technology – not collaboration with citizens, patients, etc. building on insights into what motivates them.

The role of alignment experts thus seems to be a topic for further studies. *Alignment experts* do not just speak on behalf of affected stakeholders, like the spokespersons or help with already defined questions. They make studies to align the motives and values of robot makers and affected stakeholders, based on empirical knowledge of both.

STORY FROM THE FIELD:
On collaboration with social scientists

Across REELER cases, we have three examples of social scientists, who were actually hired by robot companies and thus considered part of the team of robot developers. In one case a male philosopher was part of the core team developing at robot (HERBIE). In two other cases two female sociologists/anthropologists were hired (SPECTRUS and COBOT) in both cases by rather big companies. In both of these latter cases the social scientists had felt it a bit lonely at times, and also had to some extent to define their own positions. But in both cases, they had also been rewarded over time because the robot developers grew increasingly positive of their work. In the following story we take a closer look at the social scientist in the SPECTRUS case.

She was one of the few female employees in the organisation and the only person with a similar profile so far employed at the company. It is interesting to note that the way she was hired by the company was based on her own initiative. Given her interest in human-robot interaction and usability of technology she approached the company on her own with the offer to work for them. The robot developers in this case realised they did not know, what she could do – and asked her to write her own job application – and was very pleased when they learned what she emphasised. This shows that the knowledge on the side of robot makers in collaborating with persons coming from social sciences to robotics is still rather limited.

In general, her role in the company now is to help organise and run user studies and related workshops, meeting, etc. This is how she is involved with both end-users and the company robot makers. She is also the person who acted a contact person and helped involve the company in the REELER research. In particular in addition to being in charge of user studies, she is also involved in project management and coordination of work between different people. However, as time has passed, and because she is only one person, she feels she gets less time to do the important work with affected stakeholders – and instead is doing a lot of administrative project work.

"My job is also a lot of coordination (…) if we have some project collaborations, but I now these days focus a lot of EU projects, and that's a lot project management. (…) So, my role is kind of in between, trying to tell everyone, when they need to do what."

It is important to note that from her perspective ethical reflection and practices are not really enforced within European projects and it is up to the robotic company whether to pursue ethics or not. This may be difficult for persons with merely technical background.

"I think, it comes from the EU, and then, I think, right now nothing is really forced from the EU, so then it's up to the project and the coordinators. I think it's about pushing and pulling. So, if a developer, for examples, pulls for it, then, then that raises awareness for the ones that are leading the process. If a coordinator now would be interested in that, then he would be pushing for that, both on the EU side, and for the developers. But I think most coordinators, if you take a core robotics projects, the coordinators are very technical, and they don't think about that [ethics]. So, they are not pulling. And I don't think robotic developers are. So, they are not pushing, and the robotics developers are not pulling, I think."

Therefore, Katharina would often see herself as one who has to act as an intermediary who actually brings ethical perspectives to the company.

"I'm working a lot in EU projects, where we also develop technology that goes further in the future. So, when we develop a prototype here, then that takes like a year. And we have a concrete goal, and we want to end up this year with a prototype. But the technologies that we develop in EU projects, they might end up in a product in five years or ten years or something like that and there we are thinking more about the ethical consequences, also because it's necessary. It's standard in EU projects also, and we discuss those [issues of ethics] more [in these projects]. And we have more workshops with other companies or with other partners to actually discuss ethical consequences. Like look at what does this technology bring in five years, how does it have an impact on society, for example.

Interviewer: So, do you think ethics is connected to your particular profile? Is it easier for someone like you? How would you describe that?

It's easier for me, because I've been involved in more workshops and projects like the work you do, and then people point towards these things, and that gets me thinking about "Okay, we don't necessarily, when we do development, think about these things, but we do think about these things." And taking that back, and just, when we discuss things, saying that. And then I think it's a more shared experience."

A successful collaboration and learning related to bringing ethical thinking to the company requires making an effort and taking interdisciplinary approaches by each party involved.

"I think that [developing one's own ethical guidelines] will become more and more important for engineers as well. Either engineers having that touch, or also anthropologists having a little bit of the engineering aspect."

Though we here find a successful collaboration between a social scientist and robot makers, their motives are not entirely aligned. Katharina sometimes feels lonely, and also that she as a social scientist takes a special concern for ethics. However, EU and their emphasis on ethics also helps her in this work. As the funding agencies call for more ethical robots the social scientists can take on the role of interpreting what that means.

Finally, it is interesting to note that of the few social scientists employed in robot companies we find in REEL-ER, there is an overweight of women (see 11.0 Gender Matters).

(Based on an interview with Katharina, HRI expert, SPECTRUS)

One of the main reasons for a lack of such collaboration with social scientists is a prevalently technical focus of robotics research. This often implies taking a rather narrow perspective on robots seen as technical systems separate from humans which leaves little room for consideration of any factors that lay outside the technical domain. In some cases, robot makers do acknowledge the need and potential benefit from collaborating with social scientists, however, they still do not see it as a must or a priority, at least not yet. However, for some there is a curiosity about learning from social scientists.

Interviewer: Can you imagine collaborating with more social scientists, so artists, or sociologists, or philosophers?

Hugo: Yes, why not. Yes, remember I'm a technician and my kind of thinking is square.

Interviewer: [The way] you are thinking..?

Hugo: Yes, I'm a technician really and for me two plus two is four. So, for me to tag with society, no, maybe not. But sociology or philosophy is very interesting, very good.

(Hugo, robot developer, HERBIE)

Today it is not common that robot makers are actually collaborating with social scientists in developing ideas for projects or involving them in the design process. This seems to be tied to the fact that robots were previously kept in specially built environments like factories, where the contact with humans was limited (as robots were 'caged in' or 'enveloped'). That has changed in later years – and this may be why the robot developers (as well as the whole group of robot makers) increasingly feel a need for closer collaboration with both citizens directly and the social scientists, whose expertise lies in getting to know issues tied to people's everyday lives.

Interviewer: And in the course of your work, the design process, do you ever collaborate with social scientists, or not really?

Pino: Me personally, no.

Marco: No. No, me neither.

Interviewer: Why not? I mean, I'm not saying you should, but if you don't, then why not?

Pino: I don't know... Up to now, robots were in general automation and then humans are, let's say, operators. They're quite split. So maybe there was not much interaction between the two and not many maybe ethical issues. Maybe now that robotics is going more into collaborative robotics, meaning that the worker, the operator and the robot are working together, maybe it could be, let's say, more useful to have such kind of feedback.

(Pino and Marco, engineers, robot developers, OTTO)

However, even if there may be a doubt about what a social scientist is, they are considered useful in relation to the users in general.

> *Interviewer: Do you at any stage collaborate with social scientists?*
>
> *Cristiano: No, no, I think, no.*
>
> *Interviewer: No, would it be necessary, or not really?*
>
> *Cristiano: But could be useful for, perhaps for the approach with the user, I don't know. This could be useful, I think.*
>
> (Cristiano, engineer, robot developer, OTTO)

However, if the robots are being designed to be used by people with a technical background the need for social scientists to interpret user-needs dwindles. This is also because the focus is on social scientists as application experts helping with improving design or the psychological factors tied to robots unknown to people without a technical understanding

> *Interviewer: Do you collaborate with social scientists, like psychologists or sociologists, at any point?*
>
> *Carlo: No, not yet.*
>
> *Interviewer: Do you think it would be useful or not really?*
>
> *Carlo: I think not really, because the operators are technician [in the case of the particular robot he works on] so there is no way to interact with the normal people, but only with technicians, specialised technicians, that are going to use our robot. So, I think there is no need to speak with a psychologist or the like…*
>
> (Carlo, robot developer, OTTO)

However, from our point of view in REELER also people with a technical background can be considered affected stakeholders, when they meet a robot that will transform their work life. Here social scientists could have helped understanding present working conditions for the technicians better, thus improving the actual design and uptake of the robot Carlo is working on.

The challenge remaining is finding the right social scientists who would have a good understanding of robots and robot developers' work and could act as a bridge between robotics and ethics and people in everyday lives. In other words, in order to successfully work together, robot makers and social scientists should develop a common framework for how to understand and deal with a given subject, starting from creating a common language in the first place. This means social scientists should not only understand affected stakeholders, but also the work of the robot developers.

> *We need people that understand the problem. Not being scientists or engineers that fully understand the implications and meaning of things, that means that we need a bridge from people who have already been part of [our work], you know, that knows what we're doing. And I guess that's, that's usually… that's usually a problem.*
>
> (Jorge, Head of Laboratory, robot developer, BUDDY)

Here a robot developer points to the problem of the need for a common language, which is not so easy to obtain.

> *Interviewer: Do you find a difference between working with the social scientists and people with a technical background? And if you do, what could that be?*
>
> *Albinus: They are different because of the language they use, [laughs] for sure. And they are different because technical people use generally quantitative, while social people use generally qualitative and they are two different approaches.*
>
> *Interviewer: What difference does it make, do you think, when you work together on a project?*
>
> *Albinus: That when you are working with people with a different background, you need more time, because part of the time is devoted to create a common language, for sure. Because if you are able to start to understand each other, then you can move to work together.*
>
> (Albinus, CEO of a robotics company, robot developer, REGAIN)

This is why REELER research also shows that even though social scientists are needed in the technical sciences, they may also need a new kind of combined education that prepare them for both studies of people's everyday lives as well as a basic understanding of technical and economic issues (*see 12.0 Human Proximity and 13.0 Conclusion*).

3.7 Concluding remarks on Collaboration in the Inner Circle

Throughout our fieldworks in REELER we find that there is a close physical proximity between the collaborators in the 'inner circle' we have defined in the Human Proximity Model (*see 1.0 Introduction*). Robot makers have shared meeting places as sites for collaboration in the robotics laboratories, at EU events, competitions, fairs and conferences.[4] The people we find to be meeting in these places are mostly white males though we also find examples of female participants and people with other international backgrounds and skin colors. However, the general impression is that the group of males (*see 11.0 Gender Matters)* often appear to share a normative mindset and even backgrounds in higher education, which in our theoretical approach to defining 'collaboration' means that they share important conditions for collaborating. They share to some extent a common language and motives that bind them together. Though they are also competitors they meet regularly at these conferences and seminars to learn from each other about technical developments, political regulations and funding options (*see 1.0 Introduction*).

However, it is not all engineers but only for instance CEO's who mingle with the policymakers from the political institutions and funding agencies and company owners. In REELER some of the cases also began with an identification of an everyday problem through a contact to the end-users or other people affected by the robots, but often collaboration evolved either from groups of robot makers joint in a passion or interest for existing technology, funding possibility etc (*see 2.0 Robot Beginnings*). This already established collaboration between robot makers may also involve spokespersons (e.g. doctors speaking for patients, factory owners speaking for workers) or a mix of the above.

From the perspective of relational agency, robot makers collaborate with each other within a narrow circle that risk reinforce normativity (*see 5.0 Inclusive Design*). In anthropology normativity is something we find within any group of long-term cultural collaborations. On the positive side we see that robot makers, and their agencies, have already developed a solid set of skills in collaborative learning.

On the negative side we see that robot makers mainly include end-users as test-persons and do not collaborate with directly and distantly affected stakeholders – not even through spokespersons. They are for instance directly affected stakeholders identified as people close to the end users, who are supposed to interact with the robots without being intended users themselves. This group of directly affected stakeholders are often overlooked. An example could be an end-user who is going to work with a wearable robot system and needs a close relative (the directly affected stakeholder) to mount the equipment. Or a nurse who gets extra work when a surgical robot (to be operated by the end-user, the surgeon) is introduced in the wards. Or a worker, who loses a colleague, when a robot takes over a job-function. On the positive side, it can be a relative who gets a happier husband or wife because a wearable robot helps a patient to do tasks they could not do before. It can also be the neighbours of an elderly citizen who now gets to socialize more with neighbours because she has robots to help in the garden or house.

Even when the robot makers really try to involve people outside the inner circle, these collaborations are rarely an alignment of motives, but an instrumental use of people's expertise to forward one's predefined goals –e.g., to help solving problems identified by the robot makers themselves or to test robots.

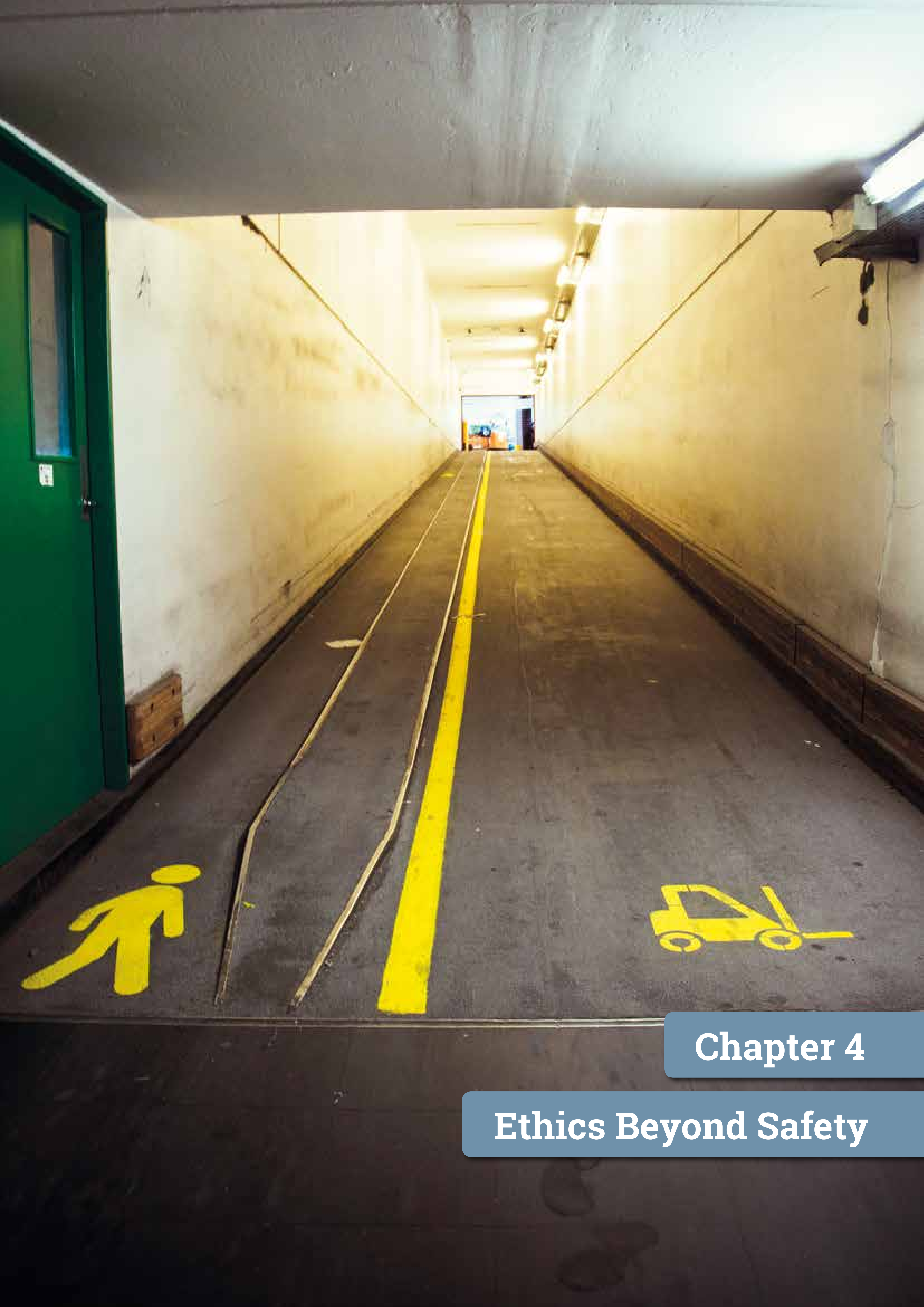
Across all cases a pattern emerges that robots are conceived (*see 2.0 Robot Beginnings*) and developed together with the powerful people in this inner circle. Making robots is not special in how these collaborations come about. Though we have not researched other business and R&D processes we expect it to be pretty common, that there is an inner circle of powerful people working together – and that users are not included as collaborative partners. What makes robots and AI a special case is both the degree of public funding involved in the production of robots, but also that these technologies may have a larger impact than what is usually the outcome of this kind of inner circle collaborations. Also, robots and AI are not necessarily chosen (like being bought on a free market) like for instance a tablet or a dishwasher. Rather, the REELER finding across cases is that there is a gap between who collaborate in close proximity to each other to realise the robot – and those affected stakeholders who are mainly invited in for testing (end-users), or not considered at all (many directly affected stakeholders and distant affected stakeholders) even when these robots and AI will eventually change their lives.

For all of these reasons, and more that are explored in parts Two and Three of this publication, we expect that more social scientists are needed to improve design, and make robot and AI more ethical in the future. However, in order to collaborate with the robot makers in the inner circle, these social scientists need a new education as alignment experts – a perspective we unfold in more detail in part Three (*see 12. Human Proximity and 13.0 Conclusion*).

4 Though robot developers participate in many collaborations with for instance Asian and American countries we have concentrated on European robotics.

PART TWO
Enhancing robot developers' awareness of affected stakeholders

In Part Two, we present and discuss empirical findings and analysis that can help robot developers directly by enhancing their knowledge of their own conceptions of ethics, and we point to the need for building relational responsibility between robot makers and affected stakeholders. Moreover, we address selected normative design pitfalls arising from the closed collaborations within the inner circle of robotics. From thinking about inclusive design, we move on to the innovation networks enabling robot developments, and a discussion of the situated practices of users in which affected stakeholders learn about real robots. With the discussion in Part Two, we hope to illustrate how the range of people typically thought of as end-users can advantageously be expanded to encompass a wider range of people also being affected by the observed robots, particularly the directly affected stakeholders.



Chapter 4

Ethics Beyond Safety

If you think for example of elder care, I mean, we don't want the elderly people to only have contact with robots. Is that a good thing? Or is that a bad thing?

(Oswaldo, industrial designer, robot developer, SPECTRUS)

◀ Some robot makers have a tendency to separate humans from machines when thinking about ethics. (Photo by Kate Davis)

4. Ethics Beyond Safety

You will find here

- Empirical examples of how the affected stakeholders and robot makers define ethics
- Examples of ethical challenges that may emerge in the processes of robot design, development, and implementation
- Overview of the main academic ethical frameworks in robotics
- A discussion of how REELER's approach to ethics differs from other ethical guidelines

You will acquire

- Awareness of how to expand safety-oriented approaches towards a holistic, socially distributed ethics
- Awareness of the need for a socially distributed ethics, perspective taking, collaborative learning, and relational agency
- Awareness of how to identify wider benefits and problems related to ethics in robotics, rather than just focusing on safety

In the REELER project, a key emphasis has been on ethics as an umbrella term covering a variety of aspects of responsible robotics and ethical robot design. Recent years have seen robots 'uncaged' from their secure environments to increasingly affect everyday lives of humans. This has ethical implications – as noted by this robot developer:

> *Whenever the robot interfaces [with] the human being, there are ethical issues coming out.*
>
> (Arturo, engineer, robot developer, REGAIN)

For that reason, ethics plays a central role in the REELER Roadmap and this publication. All of the subsequent chapters in the publication deal with issues that are relevant for the design of more responsible and ethical robots. Many of these issues overlap only to some extent with existing guidelines found and collected by members of the *Ethics in Action* workgroup, a global initiative by IEEE (Institute of Electrical and Electronics Engineers), the world's largest, international organization for engineers and technical developments.[1]

In this chapter, we take a closer look at the *concept* of ethics. What do robot makers mean by ethics, if they refer to ethics at all? REELER has found that the term is not part of daily concerns in most engineering practices (*see also Sorenson 2018 and Hansen 2018*). Many other robot makers, especially educators in the engineering sciences, funding agencies, policymakers and philosophers, think lot about what is covered by the term ethics. Engineers are often practitioners, practical people working on solutions to specific problems, and from this perspective robot developers tend to connect ethics with one main area in their everyday work lives: safety. This is a pattern across the REELER cases. When asked to reflect on ethics in our interviews, the developers and other robot makers mostly consider ethics to be about safety and avoiding small or major catastrophes. Many also consider how their products may help people and do good for mankind, but these considerations are not always connected to reflections on ethics. Despite the empha-

1 IEEE Ethically Aligned Design (EAD) workspace (https://ieee-sa.imeetcentral.com/ead)

Ethics in robot design: *Personal and collective awareness of ethical issues as well as the ability to actively engage with both ethical reflection and practices with the goal to pursue value-sensitive design and responsible research and development in robotics. The key premise is the orientation towards 'others', which includes the practice of taking other people's perspectives and understanding their motives.*

sis on ethics as safety and the notion of doing good, some robot developers do also regard humans a nuisance. They seem to have a hard time understanding end-users and (as pointed to in the Introduction) overlook the wider circle of affected stakeholders. REELER also finds a number of reasons why it may be difficult for robot developers to make ethical and responsible robots; one is that robot parts are scattered in time and space in the various design phases. Furthermore, existing ethical guidelines are often made by other robot makers within the 'inner circle', as defined in the introduction. Consequently, these guidelines unfortunately say little about the real-life problems the affected stakeholders can help to identify.

As discussed throughout the publication, the main problems with ethics in engineering is the gap between robot makers and affected stakeholders. Thus, we end this chapter by calling for a more relational responsibility and discuss how ethics in the approach REELER proposes differs from existing ethical guidelines.

4.1 Robot makers' views on ethics

Some robot developers have knowledge about ethics as a philosophical topic, but in our data material those mainly concerned with ethics in a philosophical sense are people educated to do so. Developers will, as Gunnar in the opening quotation, ponder about ethical issues when asked to do so, but in their everyday work, ethics is not their first concern. And it is often considered to be dealt with by 'ethical people' hired to deal with these matters. Thus, ethics as a general concept is generally severed off from the daily work in robot development, which is mainly technical in nature.

"When you are trying to solve this problem, you're not thinking about the ethics – you're just trying to figure [out] a solution to something technical. How do I get the robot to move this part from here, to here? "

(Robotics engineer quoted in Sorenson 2018, 18)

During REELER interviews, we have asked our interviewees for their associations with the word ethics.[2] This is done by asking them to mention up to five words they associate with ethics. They often find it is a hard question, but try to find answers that tend to move beyond their work on robots.

Interviewer: "If you were to define ethics, what is ethics? The association again, like with a robot, now with ethics."

Monika: "It's Hard. Ethics. It's like a behavior. Generally speaking, behavior that does not affect another person in the wrong [bad] way. Hard to define. Well, in my opinion, ethics is a behavior that does not have a negative effect on another person or on another being [entity]."

(Monika, scenario developer at robotics start-up, robot maker, ATOM)

Though some of the robot makers (especially the facilitators who make policies) are very aware of the concept of ethics and have given it much thought, the robot developers are often in doubt what is meant by the word – something we deal with in the section on isolated ethics.

Interviewer: "If I say ethics, how would you define ethics? From your own perspective."

Ernesto: (Laughs) "Too philosophical."

(Alph, robotics start-up founder & CEO, robot developer, WAREHOUSE)

This does not mean robot developers do not care about ethical issues, only that in their daily work these issues are considered practical and technical problems – most often tied to safety issues. As noted by REELER researcher Jessica Sorenson, this points to a "discrepancy between the way the engineers approach ethics, as a theoretical moral orientation, and the way they approach design, as a practical problem-solving activity" (Sorensen 2018, 18).

2 See Annex 1 Methods and Methodology (responsiblerobotics.eu/annex-1) for a copy of our interview guide, and Annex 2 (responsiblerobotics.eu/annex-2) for more interview quotations dealing with ethics. These annexes can be found in the digital version of Perspectives on Robots: responsiblerobotics.eu/research/perspectives-on-robots).

However, as we shall see, we have also talked to robot developers and robot makers who think beyond theoretical ethics and have a more holistic and societal view on how their robotic technologies should be ethical.

In brief, REELER identifies two general ways of relating to ethics among the robot developers:

A. Problem-solving views on ethics:
Robot developers primarily consider ethics a matter of safety. When they take care of safety issues, or find their robots do good, they believe their robots are ethical, and there is not much more to be said about ethics. Some robot developers view ethics as a 'problematic' term which is outside of their problem-solving realm. Ethics is not to be foreseen, but can appear if something goes terribly wrong. Though it can be considered unethical to cause replacement of people, or violate privacy, or have machines making wrong decisions, many robot developers do not see this as their ethical responsibility because the technology is considered to be neutral. Humans, however, may be seen as a nuisance and a problem in themselves as they slow down efficiency in robots, especially in workspaces.

B. Holistic views on ethics:
This area covers conceptions of humans in Human Robot Interaction (HRI) relations. Some robot developers take an active stance against delivering robots for military purposes, for example. Other robot developers and robot makers with a holistic view on ethics see affected stakeholders as a rich source of ideas for better design, and they express curiosity about what matter in the lives of humans.

4.1.1 Ethics as safety and problem solving

In this section we deal with the predominant association among the robot developers when asked to reflect on 'ethics'; that ethics mainly has to do with safety problems. Here, being ethical is to focus, from a technical point of view, on what can go wrong in a robot project with respect to the materiality of the robot and the presence of humans. This finding is no surprise, as general discussions about ethics in robotics have typically been associated with safety. REELER's data strongly confirms this aspect; safety is an inherently technical and system-oriented concept, often connected to regulations, rules, and standards.

The majority of the interviewed robot developers do not see it as their task to extend ethical thinking beyond how their robots work mechanically. Here are some examples of how robot developers see responsible robotics as a matter of making safe robots.[3]

Human safety: *Bodily and mental integrity of people.*

3 More quotations can be found in the online *Annex 2* at *responsiblerobotics.eu/annex-2*

I think that it [ethics of the robot] stops at the safety level. Again, we are back at the risk analysis. Because the robot has to be designed and developed to be safe, to avoid, to make [problems]. In this case, we have function of electrical stimulation. (…) And one of the problems is that they have to affix electrodes in some kind of garment, because a person with a pacemaker may decide to put the electrodes on his chest. So, we have some bigger problem. So, you know, safety has to be within the robot. Safety of the managing of the machine.

(Albinus, robot developer, REGAIN)

It is not only the robot developers (i.e., technical engineers) who mainly connect ethics with safety. The robot makers in general also make this connection. A pattern across cases is that the first association when robot makers are asked about ethics is safety tied to engineering norms, regulations, and standards. Below are examples from robot makers (a policy-maker and a business manager), who also see safety as a key ethical issue.

Interviewer: "Human workers work with robots or this type of machines. Do you think there will be any issues, ethical or other issues related to working with robots?"

Yves: "Yeah, yeah, yeah. There is a safety issue because so far autonomously acting machines were kept in cages."

(Yves, policy advisor, robot maker, COOP)

Interviewer: "We are talking about [the robot], could you think of any type of risk, of ethical problems related to the development?"

Simone: "Not necessarily. It is clear that if we are going to take a measure that concerns the safety of passengers, ethically and responsibly we need to always carry out the highest quality standards."

(Simone, sales manager at a robotics company, robot maker, OTTO)

Problem-solving thinking is sometimes applied to ethics.

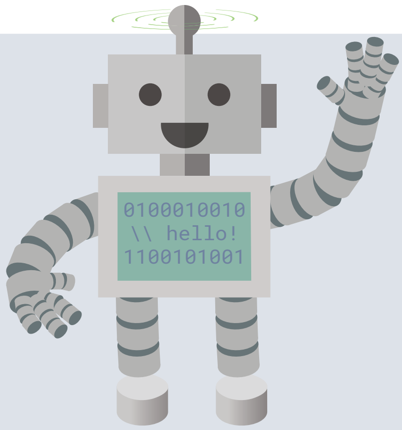
In the above preceding quotation, the robot maker sees ethics as connected to the safety of the passengers and less to as issues tied to the robot in itself, as it is not going near the passengers. However, it *is* going to be operated by the transport personnel who will be in close proximity to the robot, but Simone does not point to ethical issues in that regard: i.e. the human workers operating the robot are not in focus here.

In more recent examples of advancements in robotics and its new related fields such as Human-Robot Interaction, safety, continues to be a key focus. Even when addressing safety from new perspectives, for example how people have to work in direct proximity of robots rather than in separate environments (Bicchi et al. 2008), safety remains a dominant concern in robotics, but also one of the main advantages of implementing robotics technologies. This is not just tied to how robots are safe machines in themselves, but also pertains to arguments for why we should choose robotic solutions in the first place: because they are more safe. From an ethical point of view, this is one of the reasons some robot developers are convinced they 'do good', because their robots will be safer and more dependable than the humans. For example, some of the start-ups in that are designing self-driving cars, point to security and safe driving as one of the main selling points (in the HERBIE case). The cars are controlled by AI software that allows detecting objects and avoiding collisions while following a predetermined path. In this way, self-driving vehicles will have fewer accidents than when driven by humans. In the aerospace industry, the introduction of increasingly sophisticated automated systems in airplanes is also often justified by the need to improve safety (Mindell 2015). A similar logic guides the design, implementation and use of robots in many of the REELER cases; society demands increased efficiency without compromising safety. Here affected stakeholders often share motives with the robot developers:

> *Passengers' safety was there before and is there now. However, like all things: the speed increases, the number of trains increases, and this is a next step. But security is the foundation. So, in any case, either done with traditional tools or done with a robot, it must be safe.*
>
> (Kian, operator at the metro company, affected stakeholder, OTTO)

No matter what robot type we have looked into, whether the robots were argued to increase safety of a work task or not, safety of the actual machine developed is also an issue. This approach has often been reflected in the engineering codes of ethics that emphasizes safety in the first place (e.g. in the IEEE prescriptions – see below sections on regulations). It has been argued that in robotics, the safety issue is generally within robot software and design (Lin 2011). Given a long tradition of industrial robotics, safety has typically been associated with the system design and properties and its impact on the physical surroundings. Industrial robot applications have also been subject to numerous safety regulations and measurements that have been successfully put into practice.

STORY FROM THE FIELD:
Protect the fingers



A Northern robot company, which we here name Cobotics, has been approached by a large manufacturer which makes parts for cars and tractors. They want a robot that can work together with their human employees; they would like their workers to increase the work pace because the production has increased. The problem is the workers rivet metal plates and they cannot speed up without the work becoming unsafe. When REELER visits the robot company they are developing a new type of robot, the NITTER. For safety reasons, the robot was at first supposed to replace the human workers. But because they have run into a number of problems, they are now considering turning NITTER into a cobot that will work together with the humans. The robot could not adjust to the slightly diverse riveting tasks, so the humans still have to place and adjust the materials and remove them after the riveting.

If there were no human workers around, safety would simply be about fencing the robot and making procedures for when and where humans can enter the fence. In normal factory riveting, a robot is an autonomous tool and humans are not involved in the process. But this time, the robot is put to a collaborative task. Michael, one of the researchers in the COBOT case, explains to us that with the collaborative robot NITTER, they *"want the worker to put in the parts, it's like two sheet metal parts, and the robotic machine to rivet them together, because this riveting is all over the plates, and you need to rivet the two parts together. The riveting is the monotonous parts, but because we have a lot of work to rivet, there is just more work in getting it in and off, and making inspection from the shop floor. So, this is like a typical task. We say that if we get 2 to 3 of these robotic machines, one worker can cope with that [work of getting the metal parts in and off, and making inspection] and the worker doesn't have to lift that heavy riveting machine anymore, which is an ergonomic help, also."*

Michael also explains that the worker can qualify the process, because *"He can take a look if the NITTER is running out of rivets, something like that"*. Michael shows us that the safety issue of this collaboration lies in the fact that *"the worker can put his finger here [Michael points at a clamp], somehow, and cut his finger off. Which we solved with a pneumatic solution, so we just take care that this is closing safely and then we put the pressure on it. Because we need a certain pressure to make sure that the bolts align. Otherwise we don't get the holes riveted correctly. And next thing [concerning safety] is that the rivets have got a pointy head. And this could hurt. So, we also make sure there's no chance to interact with that tool tip. (...) We put our fingers inside and say it hurts a lot. [Laughter]. Ronald did. I didn't. I was afraid to do it. [Laughter]. I just did it after he said it was safe [laughs]."*

(Based on an interview with Michael, researcher, robot developer, COBOT)

One could argue that giving great importance to safety is a good starting point for incorporating other aspects of ethical reflection and conduct needed to ensure both safe and ethical robot design. But our analyses show that the concept of safety is viewed mainly as a technical challenge and in terms of the system performance.

In the subsequent sections, we point to other ethical issues, some of which are connected to safety while others move beyond safety. The latter concern seeing humans as problems, machines as decision makers, and machines as hackable.

4.1.2 Ethics of human machine interaction

As mentioned, ethics as safety is very prevalent when robot developers work on cobots, like NITTER. Such collaborative robots are part of frequent and close physical as well as social interaction with and among human beings, which requires even stricter safety measures put on the machinery.

So, from the moment the thing is a robot, it gets a whole different object. So, if I put myself in a dentist's chair today, and he's driving around, he has six, seven axles, I think he has no emergency stop, no safe positioning or anything else. If you have such a little robot that moves a bit, then there's an incredible safety story around it.

(Kai, mechanical engineer and cluster leader, robot maker, COBOT)

This may lead to frustration as some robot makers find safety requirements overly restrictive concerning the machines – instead of demanding humans behave differently. Humans should, for instance, learn to adjust their movements around the robots to follow their speed.

> *If I now move my head or get up from below and move my head up, I'm much, much faster, than the robot could ever move. Now I brake, the robot, moves only very slowly, but what we do not consider currently is that, yes, humans are able to move very fast. And what would I do as a worker if I hit my head on the robot? Would I say, "Yes, I stood there"? "He hit me!" So, how do I prove that I [the robot] did not hit him now, but he ran to me [the robot]?*
>
> (Kai, mechanical engineer and cluster leader, robot maker, COBOT)

Because of restrictive safety measures, some robot developers like Kai, see ethics as something that prevent them from making their systems work and deliver what they have promised. It could be a problem that humans move faster than the robot (something we also see in the case of construction robots) but it can also be the opposite, that humans slow things down. For example, whenever the operator appears in close proximity to the robot, the robot needs to slow down, and hence *"it will never finish the work"*' (Emilia, director of research and innovation, robot maker, COOP).

Thus, in the concern for safety, humans are both an object of safety and a problem; a problem because they may be more difficult to control than the robot which may prevent the most efficient solutions, as seen from an engineering perspective. In these situations, the robot developers' ethical considerations appear to center more around negative occurrences and wrongdoing when humans are involved than principles and shared values with affected stakeholders, which could guide ethical thinking and conduct.

Across cases, we find a view on human robot interaction that suggests a human-robot dichotomy with ethical implications in the field. This is, for instance, expressed through the notion that introducing robots to different sectors often involves choosing either humans or robots, rather than combining the two.

> *If you want to have result, if you want to have performance from the robot, you have to separate people from robots.*
>
> (Alph, robotics start-up founder & CEO, robot developer, WAREHOUSE)

One of the major concerns is the situation where one literally makes a choice between humans and robots in the work context. Robot developers are sometimes aware and concerned of how their robots in general affect the work force (because their robots are considered more efficient than human workers). This concern is prevalent across all cases and groups involved, including policymakers and affected stakeholders. However, from the problem-based point of view taken by most robot developers, the objective is to make the most efficient and safe robots as possible. The ethics concerning e.g. humans put out of work, is beyond this task. From the problem-solving point of view, some of the robot developers see ethics as tied to humans – not to their technology.

> *Interviewer: "Can you think of any ethical challenges related to the use of robots in warehouses?"*
>
> *Danny: "Ethical challenges? What do you mean – you mean in terms of people? I don't know. I guess that's more a difficult one for me in the sense that the nature of what I do is to sell automation solutions to customers. So, my ethics, are really borne around helping organizations to improve, being more competitive, and to allow them to have an environment that stimulates growth and opportunity. That's what I'm focused on rather than perhaps the people aspects of robotics."*
>
> (Danny, sales manager, affected stakeholder, WAREHOUSE)

Ethics of humans is, in other words, separate from ethics of the machines.

Did you say ethics? Ethics, that is something about, yes, eh I'm thinking more about humans, in any case. What is ethically correct and that is mostly what I think of. It might not make me think of robots.

(Werner, operation and production technologist, robot developer, WIPER)

This separation of ethics into ethics of humans and ethics of machines is not holistic, but problem-oriented in the sense that the problem is how to increase productivity and efficiency.

The need of higher productivity is a reality for different sectors. So, this increase of productivity and the cost of the human operator is higher, higher in particular in Europe. So, there is not the choice of the robot versus the operator: It's no work in Europe versus having the work in Europe. Or when working with the robot and an operator, not to increase the number of operators. I think it's not an [option]. We have to be able to understand this. So, the option is not to [keep humans in the loop] and not lose all the jobs, because, otherwise, in Europe, we will just not have no production.

(Emilia, director of research and innovation, robot maker, COOP)

Though some robot developers tell REELER researchers their aim is not to earn money, others emphasize that, at the bottom line, earning money in companies is what counts. Therefore, robots should not be oversold as better solutions for the employees, if they in fact are mainly beneficiary for the company owners.

And generally, it is ethically questionable [to place robots in all kinds of human environments], I think. I did many industrial applications before. We say that the robot supports the human but actually it revolves around a ROI [Return on Investment]. There we should not delude ourselves. Especially the automotive manufacturers. They use and calculate the return of investment at the moment. That means that the robot will definitely replace humans. And it is not the way that the robot supports humans, most rarely. The COBOT would like to do that but in the end the robot will be bought if it pays back for the client.

(Nathan, mechatronics engineer, robot developer, COBOT)

Here we see alignment of motives in the inner circle between some robot developers and those robot facilitators who have money to buy robots in order to make their production more efficient, which basically implies replacing humans with robots.

[I]f a robot could do twice the amount of work as a human, then I ask: [the human] needs a stop for a break, and then needs to stop working. If they [the robots] can keep going, I suppose tactically for a company or for business, that's only a good thing. For people, it's probably not a great thing because essentially it means that there's less work.

(Conor, recruitment agency general manager, affected stakeholder, WAREHOUSE)

Due to high productivity goals and the need to stay competitive, (*see 9.0 Economics of Robotization*) such a situation often seems to be more of a necessity rather than an actual choice, presumably for the benefit of the entire labor market. When it comes to the benefit of safety and efficient problem-solving, the humans are in many of our cases no longer an attractive workforce. Although robot developers do create collaborative robots, or cobots, with the aim of working together with human workers, the presence of humans is still seen as a problem in some situations.

The person [engaged] in the production is not used to having a robot like this around. So, in order to allow us to put a robot in a production line, they are asking [to] put this safety fence [around it]. Now, it's a laser as soon as the operator is arriving, the robot slows down. This means that the robot will never finish the work. Then the manager of the production will say the robot is not working, is always stopping, we don't need [it].

(Emilia, director of research and innovation, robot maker, COOP)

This also connects to some robot developers' view on affected stakeholders as 'simple people'.

And now you see more components of the system because, to work with the system, you need the elements where the people will be interacting with the robots. And by people, I mean not the robot designers but the pickers, the simple people who work in the warehouse.

(Felix, CEO advisor, robot maker, WAREHOUSE)

Rather than cobots truly working together with humans, human-robot collaboration is often limited to performing tasks simultaneously in a shared space. Here, humans are increasingly considered a problem because they have different rhythms and are perceived as unreliable. If they have to stay, production must change, and humans become a safety problem.

And there the idea is that the human is not fully trusted anymore but the robot is doing the qualitative tasks, because you can verify that. The robot does everything calmly and the human is doing the work where he cannot mess up a lot. I am already suspecting that the positions [for humans] will not become more interesting because of that, because of the take-over of the final installation by robotics.

(Nathan, mechatronics engineer, robot developer, COBOT)

Some developers therefore stress that in order not to be a problem for productivity and efficiency, humans have to change as well.

When we are speaking about collaborative robots, I have put this laser scanner [in the robot] that is detecting when the operator is coming close to it. But I always say, why is it the robot, who has to detect the human operator? Why should a human operator, knowing that there is a robot working, [not] stay far and not come [closer]?

(Emilia, director of research and innovation, robot maker, COOP)

These concerns about humans are mainly found in our cases tied to 'big scale' robotics working in production or big organizations (such as COBOT, WAREHOUSE, COOP); but there could be a tendency for this approach to humans to spill over to other sectors, as when robots are placed close to people's everyday lives in homes or public institutions, for instance. This could for instance mean changing human routines or environments (*see 5.0 Inclusive Design*). Or robot developers in the inner circle could begin to question their own capability to deal with the ethical problems arising from humans and robots collaborating.

Interviewer: "What do you associate with ethics questions?"

Nathan: "In robotics?"

Interviewer: "Yes."

Nathan: "Hm. Well. As the robot is leaving the safety zone more and more, thank God, and comes together with the people. There you have to ask the question what makes sense and what burden can we put on the human as well. Where the robot is interacting. The best example: I was at a workshop in the conference where [they told about how] the robot was put in a kindergarten. And that is kind of disturbing, if you let disturbed children, I think it was even autistic children, if you let them play with the robot. That is questionable, yes."

(Nathan, mechatronic engineer, robot developer, COBOT)

4.1.3 Ethics as a 'problem' out of our hands

Among several reasons why robot makers tend to avoid to systematically engaging with ethical reflection in robotics is the tendency to associate ethical considerations with negative occurrences related to robots and affected stakeholders (both end-users and other affected stakeholders). As already noted, in general, when asked about their theoretical understanding of the notion of ethics, people outside the academic field of philosophy, including robot developers, often find it difficult to define ethics. When applied to robotics and real-life scenarios, ethics often appears to be more of problem and a matter of wrongdoing rather than of what is actually a right thing to do. In other words, ethics has often been seen in terms of 'ethical traps' and 'dilemmas' that apply to both robot makers and robotic systems. The relation between the two is rather straightforward: to be an ethical trap, the circumstance must present an ethical dilemma. However, we should not think robots solve ethical dilemmas; that is for the developers (Miller et al. 2017). This applies not least when robot developers relegate decision-making to their machines. For instance, the dilemma of who to save if a robot accidentally threatens the bodies of two persons and only one can be saved. In this situation, the robot may be caught in a trap where neither are saved. Much of the empirical data points to the fact that when robot developers identify dilemmas and recognize that 'something bad happens', that is when they become aware and see the importance of ethical concerns. This view is shared by robot developers and affected stakeholders.

> *When you said ethical to start with, I was thinking kind of like the worse-case scenarios, like things that could go really wrong.*
>
> (Mathias, system integrator, robot maker, SPECTRUS)

> *I think a lot of the time what happens with technology is that people don't become aware of the ethical issues before something bad happens.*
>
> (Nils, university lecturer, affected stakeholder, WAREHOUSE)

Perhaps this is also why ethics has sometimes been discussed in terms of limits, i.e. staying within a certain framework that defines what robots should not, rather than should do (as we note in a later section of this chapter, this is related to the science fiction writer Isaac Asimov's proposed 'laws of robotics'). Though research should be free to explore anything, robot developments must rely on regulations, which will prevent harmful things from spreading.

> *I think all the research needs to be done – at least for the knowledge. And there are limits in implementing things, and in the fields of application, of course. This is what ethics is about.*
>
> (Arturo, engineer, robot developer, REGAIN)

For some affected stakeholders these limits should be 'in' the designers not the machines.

> *In the context of these ethical conditions, it would be every designer or programmer simply to set limits which they cannot cross and must be aware of what the values are there and how it should look.*
>
> (Bruno, city sport facilities manager, affected stakeholder, ATOM)

In any case, ethical reflection is viewed as making limits rather than an added value to robot developers' work.

With decision-making comes the question of control. By delegating more and more tasks and decisions to artificial systems (both robots and computers), humans have less and less control over such systems and ultimately the ability to take over the tasks that have now been assigned to the machine. While it may seem that we improve work conditions by assigning to humans mainly quality control and supervision tasks, in practice the key decisions may be determined by the machine and not human logic (e.g. when flying a plane or following a specific work plan). Some interviewees (in the below cases, policymakers) do not see this as a risk of technology dependence, because they see the human qualities as seriously flawed – wherefore humans should not be in control.

The main goal was to replace the control that is done manually with the tools managed by man, with an absolutely objective control that the machine can give. The control carried out by man, unfortunately like all things done by man, is also subject to errors.

(Giovanni, metro company, head of unit and application expert, robot maker, OTTO)

You need to justify yourself. You may say: 'Well, my feeling was that it would be better to do it this way', but the point is that the machine told you exactly the opposite and you decided to go against the machine and ultimately, which is probably the most probable outcome, the machine was right Then you need to explain why you didn't follow the machine?

(Yves, policy advisor, robot maker, COOP)

Some affected stakeholders seem to have more confidence in the humans.

I think whatever has to do with weapons, like police or military, it must not be a robot [who makes decisions] in any case. And other things - which is about the life of the human beings and the safety of human beings, it shouldn't be a robot making decisions, or at least has the final saying or the final word. For the medical sector I can imagine that sometimes a robot is more precise to do a surgery or whatever than a human being. But it should be the doctor deciding what the robot is doing and not the robot.

(Michael, traffic controller, affected stakeholder, COOP)

The robot developers are very much aware of the problem that also some of the technologies they make may be flawed, but it is viewed as something that is beyond their own line of work because the problem exists everywhere.

Interviewer: "Are you ethically responsible for ensuring that this robot should not be able to be hacked."

Alonso: "That's a huge domain. We say 'thieves and policemen' in Italy [constantly challenging each other]. Because there are always people who try to hack systems, people who develop systems that will build anti-hacker protection. There are directives on this about safety with tests, but it's always difficult to keep up, but this is a very transversal issue. It goes from Windows operating systems down to other operating systems; it goes up to applications. So indeed, whenever you develop an application that is really connected to the network, you are subject to hacking. But that is a really transversal, huge domain. So, in this, the producer has to develop – this is a software issue more than hardware – develop functionalities in a way that they obey the current safety directives. And then there is always someone who discovers how to enter and you have to deliver some patches."

(Alonso, participant in robot expert panel, robot developer, REGAIN)

4.1.4 Ethics of legislation

From our research it has become clear that many robot devices are technologies capable of recording information about use and users. If robots are wirelessly tethered and connected to the internet, they are not just devices that are used in particular situated locations, but can become recording and surveillance devices. Therefore, data (in the form of use, images, text, audio) can be captured by the device. Privacy and surveillance issues are found across cases in the robot developers' reflections. They also reflect on the question of AI built into robots for data harvesting. From the robots in agriculture, to industry, to healthcare, we find this problem.

I think there are ethical issues with the introduction of the robots in the robot-human interaction. Let's say you have a robot for elderly people, right? It's super amazing, but then you charge a huge price for it. Those are also ethical considerations, right? So apart from that there is also of course privacy, because I mean we are being recorded every second now. I mean if you have a phone with you, you're being recorded. There is no way around it. Yeah, and I think there is also this component of [ethics].

(Oswaldo, industrial designer, robot developer, SPECTRUS)

Robot developers often consider the issues of data protection and privacy to be dealt with by legislative measures. The policymakers have been trying to be proactive around this ethical issue. There are several directorates of the European Union that protect individual privacy and data protection, putting restrictions on how corporations (and theoretically governments) can access and use personal data of users of computer systems including the much debated GDPR regulations. [4]

Also, privacy is a core principle of the European Union. Communication and information technologies have reshaped many crucial principles and issues of privacy for citizens of Europe. Prior to the internet, robots acted as digitally connected devices and rarely linked to any wider system. Now robotic systems are often wirelessly tethered, and companies that sell their products to other companies or consumers update software systems via the internet. This means that data gathered from robots are now a currency. For ethics, this means ethics moves out of its embeddedness in a robot system. However, the responsibility of those developing robots does not seem to be likewise enhanced by anything beyond new regulations. This may be because the policymakers believe in strict and explicit rules.

> *I do believe in moral rules, which are defined by customs but also very much by the penal code and which, in a way, embodies what is considered as good or bad in the society.*
>
> (Yves, policy advisor, robot maker, COOP)

Many robot developers expect and rely on the recommendations given by the ethics committee and relevant bodies or specific individuals appointed by the company in the role of consultants. These are steps towards an effort to address ethical challenges related to information-gathering robots that even persons viewed as experts in ethics may find 'difficult' and 'disturbing' (Sparrow, 2007). Another area of legislation concerns the ethical responsibility for how and where robots replace workers. As with the surveillance and hacking of data, the choice not to employ workers (rather than replacing them with robots) is considered a problem beyond the robot developers' control. Some industries face a shortage of a suitable workforce, in particular with regards to 'unskilled' workers. Thus, rather than invest in new facilities and human resources, a company, in for example manufacturing or agriculture, may choose to implement robots that are capable of performing manual tasks in a much faster and precise manner, while working 24-hour shifts. This does not necessarily mean the company fires workers, they just do not hire new ones. Such an approach can be also described as a labor avoidance strategy.

> *What organizations may do over three to five years now is look and see what type of facilities do we require and how do we want to operate them. And one of the options they can now consider today is the use of robotic technology within those new facilities to absorb that growth of the organization. So, it doesn't necessarily have to be about labor reduction; it can be a means of labor avoidance.*
>
> (Danny, sales manager, affected stakeholder, WAREHOUSE)

This may seem mainly as a matter of an economic or political decisions, and robot developers do not express that they too have a say in creating analytical and implementation frameworks for robotic technologies, and for the way society keeps humans in the loop. Their concern is about safety and doing good with their individual robots – and following rules and regulations.

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4 With regard to large corporations, they face different issues with protecting data from hackers and thieves and potentially other corporations. Here are the directorates:

Data Protection Directive (95/46/EC) of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data. This directive specifies a number of confidentiality and security safeguards for this and other interactive on-line services.

Council Directive 83/570/EEC of 26 October 1983 amending Directives 65/65/EEC75/318/EEC and 75/319/EEC on the approximation laid down by law, regulation or administrative action relating to proprietary medicinal products.

The Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects (art I.3 and I.4 related to the careful assessment of risks to the subject), and all articles of section III Nontherapeutic clinical research, related to the obligation for patients' informed consent and right to withdraw as well as to the safeguard of patient's dignity and personal integrity.

The Data Protection Act (1988) and Data Protection Amendment (2003), Directive 2002/58/EC on Privacy and Electronic Communications (amending Directive 97/66/EC), regulating personal information protection across the telecommunications sector; ISO 13482:2014 for Robots and robotic devices - Safety requirements for personal care robots.

With the entry into force of the Treaty of Lisbon in December 2009, the Charter of Fundamental Rights of the EU became legally binding, and with this the right to the protection of personal data was elevated to the status of a separate fundamental right. A better understanding of Council of Europe Convention 108 and EU instruments, which paved the way for data protection in Europe, as well as of the CJEU and ECtHR case law, is crucial for the protection of this fundamental right (Publication on European data protection law p. 3)

Though the problem-solving aspects of the robot developers' conceptions of ethics, as well as their reliance on legislation, seem both reasonable and sensible, the perspective may have the consequence that the robot developers (as well as the robot makers and company owners in general who share their views) do not think of ethics from the perspective of the generally affected stakeholders in a moral and holistic view. However, we do see that ethics in engineering education is beginning to move beyond issues of safety and legislation.

4.1.5 Difficulties defining ethics

This, however, bring us back to the issue of who actually care about and engage in discussions of ethics. As noted, we find a huge group, both robot makers and affected stakeholders, who have a very hard time defining 'ethics' or associating anything with ethics at all. A cross-case finding in REELER is that for many of the people in the closest proximity to either developing, buying, using or otherwise being affected by robots, the word 'ethics' is not something they are familiar with – as these examples with two robot developers and two affected stakeholders show:

> *You enter this area without us necessarily sharing an understanding of what we mean by the word ethics.*
>
> (Elias, university researcher, robot developer, WIPER)

> *Yeah. Well, it's not so easy for myself to say something about ethics. Um, I should say five words*
>
> (Theo, university researcher, robot developer, SANDY)

> *Interviewer: "Five words that you associate with the word ethics?"*
>
> *Mette: [Gasping] "Help. No, that was not one of the words I associate with ethics, was it? [Laughs] Ethics. That is dignity, it is well contemplated. It is the proper. It is, it is hard... And it is exciting."*
>
> (Mette, affected stakeholder, COBOT)

> *Yeah, it's not something I know loads about, ethics. So, I'd say that the ethical questions aren't really what I work with most, but of course, in relation to this project, I, well, how can you say, I don't know, it's a question about the robot not hurting humans, that could be one thing.*
>
> (Alexander, university robotics researcher, robot maker, WIPER)

The affected stakeholders in general also seem to have a more varied approach to ethics which can range from having a good time at work to moral and not harming human values. The robot makers, whom we mainly focus on in this chapter, also connect a variety of words with ethics like honesty, thoughtfulness and behaving properly, but also, when asked directly, see ethics as something tied to the human sphere. As noted, they do seem to recognize it for the demands put on their work – but often have just as hard time defining it as the affected stakeholders. However, as a recurring 'absence' (*see Annex 1 on Methods and Methodology*[5]), 'ethics' does not emerge as something about taking care of end-user defined needs or affected stakeholders' concerns. It is either about safety, keeping up with regulations, making robots that seem evidently good or pleasing a customer.

4.2 Towards more holistic views on ethics while 'doing good'

Robot developers and policymakers, in particular, have been concerned with serving the public good and delivering work that may potentially benefit humanity (Khatib & Christensen 2010; Downey et al. 2007; Vesilind & Gunn 1998; Davis 1991). This view can be shared by affected stakeholders, who see no ethical problems because they believe robots are simply good themselves – not least when the affected stakeholders directly stand to benefit from the robots. In this case a manager:

5 see responsiblerobotics.eu/annex-1

Interviewer: "Do you see any ethical dangers or any other dangers related to the use of educational robots such as ATOM?"

Tadeusz: "No, I see the mere benefits of it. Please note, even a child who cannot write, cannot read, she or he takes it and learns programming, learns logical thinking, learns algorithms."

(Tad, science festival organizer, affected stakeholder, ATOM)

In general, our affected stakeholders believe that robots will do good. In so far they have something to say about ethics, it is not unusual to observe discussions of ethics in positive terms, i.e. in relation to guiding principles and norms we all aspire to, to a varying degree, that facilitate individual and societal well-being. However, some affected stakeholders express a different view and do not believe robots as such are able to do good. Though the believe some robots may help people (for instance cleaning and lifting) they are also skeptical whether too many robots in society will be good.

I think is not so good with too many robots. For some things it's ok but with the evolution there will be more and more and then it will not be good for the people.

(Anita, cleaning staff, affected stakeholder, SPECTRUS)

In contrast to the notion of ethics as safety and to avoid evil or unwanted interactions with robots, some robot developers simply find *"a robot is a machine that helps a person"* (Edgar, system architect, robot developer, SPECTRUS).

And some robot developers see themselves as people who simply do good, for mankind, simply because they develop robots.

I am still positive. And not because I'm a robotics person. I'm not telling you this from a business perspective or because this way I will become richer. It's not for that. It's because I strongly believe that the robot can help mankind.

(Alessio, robotics start-up founder, robot developer, COOP)

Some of the robot developers are, however, aware that a wider ethics cannot be separated out from technology – and that the technology cannot 'do good' by itself. Even if the technology may seem 'neutral', these robot developers are aware that they share a responsibility with users for how a robot is used to create unsafe situations for other humans:

We are responsible for the technology we develop, of course. It can be used in one way or another, it is always the same. I mean, the military uses of robotics. I am part of the robotics and the AI-research community, and we make many manifestos, many documents asking politicians to regulate.

(Carla, robot developer, BUDDY)

Some robot developers can even see themselves as affected stakeholders, when it comes to ethics, even if they do not connect these considerations with their own robots.

Interviewer: "Then we also have questions regarding the topic of ethics. What do you think of when you think of ethics?"

Valerie: "I kind of imagine safety for humans, but, well, physical, but also: 'What is happening with my job? What is [happening] with my life?' Like that."

(Valerie, mechanical engineer, robot developer, COBOT)

Robot developers do try to put themselves in their users' place when they point to safety as not only physical but also psychological human well-being:

A big challenge is to make sure that the robot is safe enough to interact with a human. Make sure that you will never involuntarily harm him or scare [him] – not even harm, but just scare the person that's in front of it. When the robot starts moving, suddenly it's quite normal that people get a little bit surprised and sometimes frightened and don't want to interact anymore with the robot.

(Daniel, software developer, robot developer, BUDDY)

In our case material it seems that the developers' ethical considerations are also sometimes tied to the size of the company. Big companies have special people dealing with ethics whereas in smaller companies they try to develop an all-round approach to ethics which includes the engineers. For example, some companies are small enough to allow the employees to spend time discussing a given ethical concern.

Usually we get together, we sit, we speak and then we take a decision as a group. It is a young, small company, so if I have some ethical doubt about something I will just go directly to [a name] or to [a name], which is our CTO, or to whoever is relevant at the moment, grab a few of them, let's talk about this, let's take a decision on that. And then we will sit together, we will take a decision and we will decide where we go. We do not really have a specific process; we just get together and decide things.

(Daniel, software developer, robot developer, BUDDY)

We find the greatest awareness of ethics in some particularly concerned engineering educations, where ethical considerations also comprise trying to include more women in engineering.

A holistic ethics takes into consideration the whole person and their physical and social environments.

STORY FROM THE FIELD:
How to teach ethics

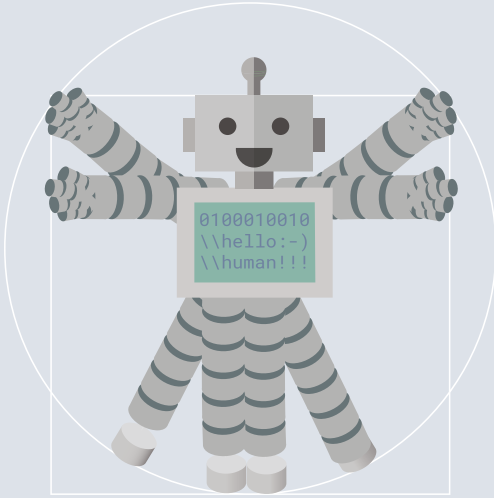
Many engineers across cases tell the REELER researchers that they did not learn much about ethics during their education, but this may change. In fact, one of the universities taking part in REELER's research has, in the past 15 years, radically transformed their engineering education to teach ethics in a more holistic way. REELER meets Elias who is a professor at the university in Northern Europe and tells us about this development.

"I think, most engineers think about [ethics], when you start working with real projects, which we also do alongside our students. [We want] to have a more holistic point of view. One thing is if you just need to create a gadget in this phone that will be able to do this and that, but when you look at how I'm using a phone as a whole, how the user uses it and what does the user require and stuff like that, then you actually begin thinking about these things."

We hear that previously (maybe 10-15 years ago), an engineer was considered a nerd, who was detached from society, and thus might create something harmful because they were 'out of touch' with people. Consequently, they used to teach ethics to engineers by emphasizing how things could go really, really wrong. Today, both the image and the practice of engineering have changed, and it is not uncommon to *"have projects with the students which help people who have limited mobility or something like that. Then you go out and talk to these people and get an idea of their world."* Contrary to previous teaching of ethics, this university no longer emphasizes the problems and the dilemmas.

"I actually think we did that, in old days. Just when [the students] started, we had these ethical dilemmas we put in front of them. They did that with a lot of commitment. But I don't know how much they learn from it in the long run. [Today] with the broad approaches we ask the students critical questions. We say: 'Hey, listen, what does this mean for the user, this thing you're doing?' Or whoever is going to use it, society, or the company, or whatever."

Elias emphasizes that the word 'ethics' has come to mean studying and working together with users – and it is *their* ethics that matters.



"Well, I don't know, what we mean with the word 'ethics' but now we are coming and looking and working with users. You get to be a part of their ethics, like, their world. No matter if it is something that matters to us, right, and can it cost more. Yeah, I don't know, I think there are a lot of aspects related to ethics."

Contrary to the more problem – and safety-oriented engineers, Elias and his colleagues find it important to take responsibility for how their engineering work also affects society and wider contexts.

"Today I'd say that we have a clear view for them [students] to go out and work in a context, where both society and people are an important part of the success criteria and framing conditions. So, you can't create anything technologically isolated without having to decide your position in relation to it. Especially not if you have [a] more holistic education, which I think we have a lot of, then you can't avoid being a part of those conversations."

Elias explains further that in the past 15 years a number of engineer courses has popped up - not just at his university, but in various places - where design and the wider context are also included in ethics teaching. Here, particularly welfare technology, is an example of a domain *"where you go in and teach something else than purely techniques and technology"*.

(Based on an interview with Elias, university researcher, robot developer, WIPER)

Very few across the REELER cases seem to share the impression mentioned by Elias that ethics is about *"coming and looking and working with users...You get to be a part of their ethic, like, their world."* (Elias, university researcher, robot developer, WIPER).

This may be because the idea of thinking of ethics holistically and beyond the machines is still new. Most robot developers still feel they need ethics to be something they can put into a formula – which is not possible with a distributed, holistic ethics.

4.3 Beyond the robot makers' views on ethics

In addition to the robot makers' own views on ethics and our analysis of ethical responsibilities tied to the robot developers' own associations, we will explore one more theme in this chapter. This is the issue of how ethical concerns are distributed. This theme is *not* addressed by the interviewees themselves. Nonetheless, our analysis across cases identifies two problems tied to ethics that are rarely dealt with in the extensive literature on ethical guidelines for engineers.

The first concern is the inherently *distributed* character of robots. A robot consists of many different technical hardware and software parts and thus we should expect that the ethical responsibility for making responsible robots is distributed accordingly. In none of our cases is the robot developed in one place only. It is always developed in many different places, by different people. In a typical case, some robot developers take care of, for instance, software, while others handle the hardware, a third group integrates the two and others take care of marketing. Sometimes a particular person is appointed to take care of ethics. Acknowledging this fragmented distribution of responsibility for robot parts, raises the question of where to place ethical responsibility: Is it in the software, the hardware, the assembly, the management, the marketing, or the appointed 'ethics persons'? Furthermore, contrary to the expected, we do not find ethics distributed across all of these aspects of robot development. Ethics, as a professional concern, is rather *isolated* in special departments, or groups of professionals, where it is identified and debated in a closed set of people. In other words, the parts of the robots are distributed, while the ethical debates are isolated (or 'undistributed').

A. Robot's parts are, as material objects, geographically distributed, which risks to dilute ethical concerns for the robot as a finished product.

And at the same time,

B. Ethical concerns are fairly isolated i.e. only concerns a smaller group of people in ethics committees and philosophy.

4.3.1 Distributed technology = distributed ethics?

Design of robots is distributed across time and space all over the globe. It follows that ethics should be likewise distributed, but this issue has not been dealt with in the robot maker's reflections.

In our analysis of our general data collection, which included many visits to robot laboratories all over Europe, we found a pattern of ethics not being brought up by any of our interviewees and which is also hardly touched upon by philosophical or academic papers in general. However, as we define ethics in robotics we must take into account that technology is *distributed*.

In all the 11 case studies of different robot types we find a similar way of working: robots are never built in one place (from scratch). This will not come as a surprise to those who build robots, but it does raise some questions about how to make ethical and responsible learning in robotics, when the people and technologies are often only connected occasionally – and robots are tested as assembled in the later phases of a project. Furthermore, in all of our cases, the robot developers never build a robot from scratch but include 'off the shelf' components, which they themselves do not feel responsible for. Within each case, the technical parts are developed in different places by different people, even in the biggest companies. This is a finding across all cases regardless of robot type.

In one case, SANDY, a university in Spain is coordinator and responsible for software parts, a university in Belgium is responsible for making obstacle detection and viewpoint analysis, a company in Sweden works on grippers, a company in Turkey on autonomous mobile platform, a company in Netherland takes care of testing and a Swedish university takes care of dissemination and analysis. This may look like a typical EU project with cross-country collaboration, and we have a couple of these in REELER. However, this pattern applies, to some extent, to all the cases – whether distributed geographically within Europe or disciplinarily within a single company. The point is that with a very distributed technology, ethics *should* be both distributed and centrally coordinated to ensure the assembled robot is ethical. Yet, we see no indication of this in our data. On the contrary, ethics is often delegated to special people with special functions severed from other parts of robot development.

> **Distributed ethics:** *Making robots is distributed – but that also means ethical responsibility for the whole project should be distributed.*

If no one in a robot developing group takes responsibility for the ethics of all the robot parts, a robot, with software that turns out to be hackable, can become unethical, even if all the other hardware parts have been carefully evaluated as ethical. Put differently, the ethical responsibility for a given robot lies not in its separate parts but also in the way they are combined, and eventually the way they are used and misused. In this way, ethics in robot technologies is inherently a matter of relational and distributed responsibility.

STORY FROM THE FIELD:

Distributed ethics – the EULA robot

On K-BOT's premises in a Northern European country we find several factory halls and warehouses. K-BOT robots are combined with other K-BOT robot parts and several robot cells are showcased. EULA is one of K-BOT's newly developed robots. The innovative development of novel robots takes place in two offices: the Innovation Office (INO) and the Company Investigation Office (CIO). It also involves collaboration with many suppliers across many processes.

In INO the employees try to think 10-20 years ahead. They work with *"futurology"*, as Peter, Innovation Manager, explains in an interview. Johanne, also Innovation Manager at INO, explains they are involved in *"blue sky"* research, and several interviewees mention that INO carries out *"the evangelism of robotics"*, a term Peter uses himself and which spreads the gospel of robots' blessings. Both Johanne and Peter often represent and promote K-BOT at fairs and conferences accompanied by the CEO. They are spokespersons for K-BOT at conferences, in newspapers, and in robot and business associations.

From a REELER perspective, ethical considerations should be part of the futurology efforts just as the ways K-BOT present robot futures can evoke ethical issues.

CIO conducts research in novel robot developments. Some of the researchers also call this the pre-development department because it comes before product development. Here, the robot developers work on projects that are still 5-10 years away from being a marketable product. As one robot developer quoted himself saying to K-BOT's management: *"It's research! You cannot sell it!"* CIO has approx. 30 employees (not counting unsalaried students and salaried student assistants) to develop ideas for future productions, and write grant applications, reports, etc. CIO has stable funding from the company's own sources and is, according to Kai (cluster leader in CIO), not dependent on research grants.

This type of work also calls for ethical considerations as the ethical responsibility, to some extent, can be seen as distributed among the application writers and the grant providers.

Robot developers and innovation economists generally advocate for researchers to follow their own research interests in research and development (R&D) phases, across publicly funded research projects and independent of grants. K-BOT's robot EULA is made in this way. It is the result of a technology first developed at the State Aerospace Centre, then moved to the K-BOT company which developed it to its present TRL9. Today, the robot is in mass production at a K-BOT factory.

To develop and build EULA, engineers have been working in different teams. Some teams are responsible for the mechanical constructions, other teams make the control system and the control cabinet. Others develop the software. A design process of a new robot usually takes a year and involves several meetings between a chief designer and different groups of engineers, those who do the cabling and those who insert the motors, etc., where the designer refines and adapts his design.

Different companies and subcontractors deliver the parts for EULA. The transmission equipment is, for instance, from *Smooth Drive*. The motors come from *PS Systems*, and the sensors from *ReadyDrive*. Both *PS Systems* and *ReadyDrive* are spin-offs from the State Aerospace Centre. The rolling bearings come from a Dutch company (*The Dutch Ball Bearing Company*), a French company (*TXT*), and other big bearings companies. In the R&D phase, the prototypes are typically 3D-printed, but ultimately, they will be produced either by K-BOT itself or by a range of other companies.

In another case, one of EULA's mechanical parts is combined with biopsy equipment, so that it can make biopsies on cancer patients. This has many applications and will affect many people (male and female) and their work environments. Consequently, all of the various applications involve ethical aspects.

EULA can also be seen as just one component, e.g. in an assembly line where it is integrated by system integrators such as the system engineers from K-BOT's own Application Engineering Team. It is always necessary to integrate, coordinate and match EULA, and other robots, with the other business customer's – and operators' – needs. Here a number of ethical aspects arise.

Above all these different departments and processes is K-BOT's management and board. Parallel, and not part of this chart, are divisions in other parts of the world, not least USA and Asia.

The K-BOT company has its own ethical officers who invite company staff to take, for instance, electronic courses in ethical behavior. Their work is, however, severed from the other departments, and ethics consequently becomes rather detached from the actual development and sale of EULA.

(Based on interviews with Peter, Johanne and Kai, robot developers, COBOT)

4.3.2 Isolated ethics

As in the EULA case above, the people knowledgeable about ethical issues are often experts who actually are interested in and debate ethics. Across cases in REELER, they seem to constitute a small group of people tied to certain functions – whereas the main bulk of interviewees are not engaged in these debates. This leave their voices out of the debates.

From a REELER perspective, this raises the question who is given voice when it comes to ethics in robotics? We have tried to give voice to a new group of interviewees, the affected stakeholders, but it has not always been easy. One of the ethical challenges identified within the REELER fieldwork emerged in relation to the process of participant recruitment for our research. In general, in order to involve an individual employee in the REELER study, an approval needs to be obtained from a relevant supervisor. In several cases, an employee expresses interest in participating in the interview, but for different reasons he or she could not obtain the needed approval *(see Annex 1 Methods and Methodology)*.[6]

To give voice to this group of people is definitely beyond the responsibility of robot developers, but it is connected to the issue of who is given a voice within the 'inner circle of robotics' *(see 1.0 Introduction)*. Customers and clients (people who buy robots) definitely have a say, but the same does not go for the people eventually working in close proximity with the robots or otherwise affected by them.

Furthermore, it is important to note that while, in theory, many of the committees in the area of Robotics/AI Ethics are open to anyone who is willing to contribute to these areas, in practice, they usually consist of the individuals who come from academia, industry, or public institutions, and hold a certain degree of power or a relevant position. In other words, there are only limited possibilities for the average end-user, such as manufacturing workers or middle-level managers, to participate in research or initiatives that would influence guidelines for responsible robotics and ethical robot design.

This poses serious questions about the validity of work on robots and ethics, where only a small group of individuals decides on the fundamental issues that affect society as a whole. Also, serious ethical concerns emerge with regards to the transparency of projects and practices in robotics R&D, with particular regard to projects that are often partially or fully publicly funded. Following the assumption that 'whoever understands what the robot can and can't do, has responsibilities assigned' (to paraphrase one of the REELER participants), one could argue the main way to create an inclusive framework for robots and ethics, and to increase transparency, is through education that would apply to all.

It is interesting to note that several study participants argued that ethics should be 'a must' in robotics. This includes imposing the approaches that would actually force robot makers (both at the individual and institution/company level) to incorporate ethics into education as well as professional practice. The latter includes imposing top-down approaches that potentially could come from the European Commission, something that the Commission itself has suggested in the document *Artificial Intelligence for Europe*: 'the importance of ethics in the development and use of new technologies should also be featured in programmes and courses' [7]. The way ethics could be imposed in robotics research is of course through legislation as well as different types of guidelines that may also become part of legislation. In any case, however, in order to be effective, education and regulations related to ethics should eventually become a part of the robotics culture in a holistic approach to ethics.

> *If you think of the technical side, you could implement regulations of what robots can do and what robots cannot do. That's one thing, but I think if you teach this ethics for the people that are going to design, then you create this culture.*
>
> (Oswaldo, industrial designer, robot developer, SPECTRUS)

Nonetheless, the question is whether it is enough to change the culture of engineering – and whether the responsibility for ethical robots should be placed solely on the robot makers (the developers, application experts, and the facilitators who fund and make policy regulations)? This question seems to be a new one in the existing discussions about ethics in the robotics community.

4.4 Ongoing theoretical discussions of ethics

In order to identify whether REELER can bring something new to the ongoing discussions of ethics, we have made a review of ethics in relation to robotics. As already mentioned, the present discussions of ethics, relevant as they are, do not seem to have great effect in the community of robot developers. Another point we want to make is that while the discussions identified in our review on ethics are all relevant, they overlook two important aspects. Discussions focus on areas like safety, robot rights, taxation, and robot autonomy, but largely seem to overlook the problem that a) affected stakeholders' motives and perspectives are missing when robots are conceived and created, and b) ethics is difficult to work with unless underlying motives are aligned and the distributed character of robot making is taken into account.

6 see responsiblerobotics.eu/annex-1

7 https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF

Ethics of robots is still a fairly new field. Ethical inquiry in relation to the design and use of robotics goes back to 2002, when IEEE held its first ever workshop on roboethics, but ethics as a discipline goes back millennia. In broad terms, ethics can be understood as the inquiry into right and wrong – both in relation to the individual and society. More precisely, many debates refer to *normative* theories of ethics, i.e. theories dealing with how individuals *ought* to act (Driver 2007). Traditionally, such normative theories have figured in the design of robots under the heading of *engineering ethics*, a field that dates back to the 1970's (Weil 1984). Engineering ethics is concerned with identifying and grounding moral conduct of engineers in their practices, but has often been bogged down in theoretical discussions about the need for codes of conduct (Luegenbiehl & Puka 1983). Such discussions have engaged with the three, dominant ethical traditions: *deontology, utilitarianism,* and *virtue ethics* (e.g. Martin & Schinzinger 2005).

This chapter will not provide an in-depth account of each of these; however, we will provide a very rough outline. Deontology, the study of *deon* (meaning duty) is the study of moral obligations. On this account, right conduct is acting in accordance with some duty or obligation, e.g. don't kill innocents – no matter the consequences (Alexander and Moore 2016). Deontological consideration often underlies strict codes of conduct specifying the duties of engineers, e.g. from the American Society of Civil Engineers (ASCE):

"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties." (ASCE 2017)

This highlights an often-voiced criticism of deontology, and of many such codes in robotics – they do not provide actionable guidance (e.g. Sorenson 2019). Turning such imperatives into actionable practice often requires serious interpretation work, which everyday duties leave little time for (Ross 2007).

Utilitarianism, often popularly surmised as "the largest possible good for the largest possible amount of people", claims that the good lies in the maximization of total utility. Utility can be cashed out in different ways, but it is traditionally done in terms of happiness. On the utilitarian account, an action is good to the extent that it results in an increase of the total amount of happiness in the world. Such approaches are rarely codified, but often serve as the default mode of reasoning about moral issues. REELER research problematizes this approach in robotics. If it is left to the 'inner circle' to define the 'happiness' brought by robots, it glosses over the many unheard voices of affected stakeholders.

Finally, virtue ethics centers on the cultivation of virtue, and does not provide a rough-and-ready recipe for action. Virtue is defined as a habituated, characteristic, proportional and reliable disposition to act in a certain way (Annas 2011). For instance, embodying the virtue of generosity is to be motivated to reliably act generously (more in times of abundance, less in times of need), and to feel good about doing so in a way, which is in accordance with the agent's character (Annas 2011). In relation to REELER findings, virtues are no guarantee for responsible and ethical robots, as even the most virtuous robot developer may overlook stakeholders' needs and concerns if not learning about them.

4.4.1 Theoretical safety perspectives

However, REELER's review of ethics reveals that for the most part, ethical concerns in robotics are on safety, autonomy, and robot rights. In early papers exploring robot ethics, the model of ethics from Issac Asimov's short story Runaround (1940) were cited regularly:

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

A robot must obey orders given by human beings except where such orders would conflict with the First Law.

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

It is surprising how frequently these 'laws' are mentioned in academic papers on robot ethics. They are also surprisingly often referred to by the robot makers in REELER's data (a fifth of our interviews with robot makers refer to Asimov's laws). In practice, these laws are considered too sophisticated to program into robotic systems that rarely can operate autonomously for significant lengths of time without some human supervision (e.g., driverless car, social robot).

Furthermore, Asimov built on a thought experiments, and had no idea of how complex a situated practice with the actual robots developed can be. Thus, through REELER's data we identify a gap between how some robot makers (e.g. EU and ethics experts) envision roboethics and robot regulations and the actual work on robots. The robot makers referring to Asimov in general seem fully aware of this difference, but also refer to it as an ethical guideline. This could indicate a need for a more comprehensive understanding of ethics that takes root in situated everyday lives (as attempted by REELER).

Do REELER results add other new perspectives on the debates on safety? Of course, robot developers have long been aware of different risks related to the implementation of robots in the proximity of human beings. However, efforts to address what could be seen as ethical concerns have been traditionally limited to the consideration of human safety (bodily and mental integrity of people) in close proximity to machines only.

In general, starting from the 1970s, the field of engineering ethics has emerged with a focus on safety. In line with the engineering principle of serving the public good, different institutions and organizations formalized engineering ethics into codes, canons, standards, etc. (for a detailed discussion, see Sorenson, 2018). Most of them emphasize human safety

Safety is the most common association made by robot developers, when asked about ethics. (Photo by Kate Davis)

in the first place.[8] Much of what is written here is in line with those robot makers, who also consider ethics to be first and foremost about safety. Such thinking applies to robotics-oriented design approaches as well as different engineering codes of conduct and legal regulations. A recent statement by the European Commission on AI, robotics, and 'autonomous systems' also points to safety and security as one of the key ethical concerns (European Group 2018).

Safety related to the robot's contact with a human being has also been viewed as an inherently technological challenge (Association 2013, 1631), as also found in REELER research. One could be asking, however, what makes ethics particularly important for the current developments in robotics. One of the main reasons is in an increasing and close integration of robots into our society: The moment robots are placed in the human physical and social spaces, these new ethical concerns emerge. Traditionally, to a large extent safety was ensured by keeping people away from robot 'caged' or 'enveloped' robot workspaces (Floridi 1999). However, the moment people and robots get to share physical (and social) spaces, the application of 'a segregation paradigm' (Bicchi et al. 2008) is no longer possible. With new types of robots that go far beyond industrial applications, these new challenges of human-robot interactions (HRI) emerge. New types of robots endowed with an increasing degree of intelligence and autonomy as well as situated not only in the physical but also human social spaces, have emerged with new ethical concerns. And yet, the ethics in robotics, as confirmed by REELER, continues to be seen mainly through the safety perspective without addressing these wider ethical issues through research.

However, the need to address such concerns in a systematic manner has resulted in various efforts made to develop research and legal frameworks for responsible robotics and ethical robot design. The strong emphasis on certificates and legal regulations that ensure that robot as a product is safe for its users fits with the applied and technical nature of robotics research. These include, for example, safety regulations for the machinery used for industrial applications.[9] Many new types of robotic systems like autonomous cars have yet to receive appropriate regulations. Others, such as personal care robots, have already been addressed in terms of safety

8 **Institute of Electrical and Electronics Engineers:** We, the members of the IEEE ... agree: to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment. (IEEE 2018)

American Society of Civil Engineers: Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties. (ASCE 2017)

National Society of Professional Engineers: Engineers shall hold paramount the safety, health, and welfare of the public. (NSPE 2007)

9 ISO/TR 20218-1:2018(en) Robotics — Safety design for industrial robot systems — Part 1: End-effectors; SO 12100:2010, Safety of machinery — General principles for design — Risk assessment and risk reduction

requirements , or otherwise fall under existing sectoral or industry regulations (health privacy laws, for example).[10]

Over time, the notion of ethics in robotics has begun to expand beyond safety addressed mainly in terms of physical injuries or damages to health and related direct human-robot interactions. For example, on the one hand, the British Standards Institution (BSI) standard *BS 8611: 2016 Robots and robotic devices*, builds upon the existing safety requirements for different robots; on the other hand, it makes it clear that the Standard in question views the question of physical hazards and safety design features as part of ethical design, but that these are covered by safety standards. In other words, 'Ethical hazards are broader than physical hazards'.[11]

A typical approach, however, is to address wider ethical frameworks in robotics but still link them back to the question of safety. *The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems* launched in 2016 by The Institute of Electrical and Electronics Engineers (IEEE) is a good example. The initiative brings together hundreds of experts and stakeholders with the goal to inform and influence debate and work on the autonomous systems in a way it is guided by human-centered values and priorities human well-being. While the initiative follows a broad perspective on ethics according to which 'ethical' is not synonymous with 'safe', safety is still a recurring theme across different areas covered in the report and it appears among the main indicators of the human well-being (Ethically Aligned Design, Version 2 (EADv2), 2017). Also, when discussing ethical principles in robotics and roboethics, the European Commission and related European Parliament's Committees tend to put an emphasis on the 'protection' of human persons, in particular human basic rights and freedoms (e.g. human dignity or liberty) (*see for example European Parliament 2017*). In this sense, the main focus remains on a person's bodily, mental, and social integrity with robotics technologies being seen as a threat.

Throughout this publication, REELER adds a number of perspectives to the ethics as safety approach through ethnographic research into people's everyday lives – notably that humans are whole persons and their engagement with robots should be viewed holistically not just as a matter of technical dependability and safety.

4.4.2 Autonomy and ethics

Ethics in philosophical debates, policymaking and general academic papers often discuss the ethical implications of robot autonomy. REELER's data does have some references to robot autonomy in relation to ethics – but not so much as found in the general academic literature on robots. This is probably because there is a huge awareness among robot developers (however not the policymakers) that robots are in the end no more autonomous than allowed for by their human controllers – and no more autonomous than the batteries or electrical cords allow.

Furthermore, experts in the field agree there is no commonly accepted definition of autonomy in the AI or cognitive sciences (Frose et al. 2007, 455; Vernon et al. 2015). Autonomy of a robot implies some degree of freedom from its human controller (Frose et al. 2007). Autonomy may be set on a continuum with autonomy at one end, and heteronomy (its antonym) on the other. Or as a spectrum that includes different kinds of self-determination of a system: autonomy, supervised autonomy, or behavioral autonomy, operating in the same system. One such definition of autonomy is given here.

Autonomy can be defined as:

"the degree of self-determination of a system, i.e., the degree to which a system's behavior is not determined by the environment and, thus, the degree to which a system determines its own goals". (Vernon et al. 2015)

Behavioral autonomy represents a form of autonomy that is behavior led. Behavioral autonomy can be characterized by at least two distinct attributes:

(a) the degree of autonomy (i.e. the extent to which a system is assisted by a human in the achievement of its goals and the execution of its behavior), and

(b) the strength of autonomy (i.e. the extent to which a system can deal with uncertainty or unpredictability in any aspect of achieving its goals). There is a continuous spectrum of both degree and strength.

However, even in AI, the human controllers decide what is the ultimate goal of the 'autonomy' displayed by robots.

It seems that a lot of attention in ethical debates is paid to an issue which is not yet as relevant as many of the aspects on ethics unfolded in this publication. After all, machines are built by human robot makers and roboethics is 'human ethics applied to robotics' (Veruggio et al. 2011). Thus, from a REELER perspective, the concern is about human decisions on autonomy, not the autonomy of machines.

When REELER began its studies, we expected to find many ethical issues tied to machine built-in autonomy, but in practice this seems to be an overrated ethical concern tied to the idea of 'autonomous, intelligent robots' prevalent in media representations *(see 8.0 Imaginaries)*. The problem with this misconception is that this *also* may be seen as a way to relieve the robot developers of their responsibility for ethical thinking and agency. If the robot is autonomous, so, it could be argued, is its ethics.

10 ISO 13482:2014: Robots and robotic devices -- Safety requirements for personal care robots

11 BS 8611:2016 Robots and robotic devices. Guide to the ethical design and application of robots and robotic systems

4.4.3 Robot rights

Closely tied to these discussions is the debate on robot rights – which seems to stem from a conception of robots which is completely out of line with what REELER researchers have found. Even the most social robots in our sample (ATOM and BUDDY) are so much machines that the idea of granting them robot rights is misleading. Not least in terms of ethics.

The strong focus in Academia and policy making on robot rights does not seem to be grounded in any real close proximity to actual robotic devices *(see 1.0 Introduction)* – and the consistent talk of future intelligent beings is out of line with the real robots created by robot developers (e.g. one of our participants has talked about a Hollywood version of robots).

In January 2017, the European Parliament began to draft a new set of regulations as part of the Commission on Civil Law Rules on Robotics. The document proposes to regulate the development of robots, so that the technology is developed safely, considering the ethical and social effects of the new technology. Moreover, the Fourth Machine Age (robots and AI) is predicted to radically alter work practices across the world, as robots and AI replace human jobs. The impact of these developments could increase unemployment while simultaneously reducing social security payments in the form of taxation or national insurance contributions to nation states. As a way of addressing this potential issue, the Committee on Legal Affairs propose the introduction of the term 'electronic personhood' for robots, to make companies and corporations liable for potential harms of the technology and reduced funding for state welfare provisions.

Personhood is a legal category, designed to indicate rights, responsibilities and obligations. Personhood is a controversial category, as it has historically been applied to both persons and things. The concept of 'corporate personhood' for instance developed in parallel with the concept of 'the person' in Western liberal democracy. The person was a legal construct that evolved out of the Enlightenment humanism (Davies and Naffine 2001). The use of the term 'person' is not without its problems. The person became a legal category at the onset of the liberal western democracies. The term 'person' was used in the US constitution's Fourteenth Amendment which included the rights of free slaves to be recognized as 'persons' and was later taken up as a term for corporations to be able to access the same rights as human beings. This is termed 'corporate personhood'. The extension of the political franchise to include those other than wealthy white men, was gradually extended over 400 years to include Black people, former slaves, working men and all eventually all women. In extending the franchise, inherent in the legal personality was a new way to represent humans as forms of property.

The attribution of the category of 'personhood' to robots opens up a minefield of issues from a human point of view. If a robot becomes a person, for example, does that mean it will need (is entitled to) the same treatment as a human being? Will the robot need holidays and breaks? Will it be 'cruel' to use a robot as an instrument?

From REELER's perspective, these questions seem superfluous compared to the real problems encountered by affected stakeholders, who in some cases are not really considered persons by robot developers, but nuisances and threats to efficiency and productivity. These real ethical problems, covered by REELER, seem to be more or less unnoticed by the ethics communities – and in any case overshadowed by the (granted!) much more spectacular debates on robot rights.

4.4.4 Roboethics

Roboethics: *A field of ethical inquiry, which deals with how humans design, interact and relate to robots. In particular, how to ensure that the spread of robotic technology benefits rather than harms humanity.*

Since at least 2002, another field of ethics has sprung up, which deals specifically with robotics. This field, called roboethics, discusses the ways in which we design, use, and relate to robots (Sullins 2011) and it has continuously been a source of inspiration for REELER.[12] This new way to address ethical challenges in robotics places a responsibility on the engineering culture rather than just relying on regulations. Given its highly interdisciplinary character and a relatively high participation of social scientists and philosophers, roboethics has the potential to actually widen the scope of ethical reflection in robotics and bring it beyond narrow safety-oriented considerations. From a research point of view, roboethics covers a large variety of perspectives and disciplines that may significantly vary in their focus and approach (Tzafestas 2018; Crnkovic & Çürüklü 2012). While some approaches involve assigning ethical and moral capabilities to robotic systems (e.g. (Wallach & Allen 2009; Arkin 2009), a dominant approach proposes that 'roboethics is not the ethics of robots, nor any artificial ethics, but it is the human ethics of robots' designers, manufacturers, and users' (Veruggio & Operto 2008, 1504).

On the one hand, since its foundation in 2004, the field of roboethics has been growing. Since the early 2000s, a number of conferences, symposia, and workshops on roboethics took place, from the events associated with technical conferences such as for example ICRA (IEEE International Conference on Robotics and Automation) to the conferences fully dedicated to ethical standards in robotics or 'robophilosophy' (for a detailed review see for example (Tzafestas 2018). Other examples include providing guidelines in the form of a Roboethics Roadmap (Veruggio 2006) or a taxonomy for roboethics (Steinert 2014).

Roboethics also deals explicitly with the relation between media representations and the 'uncaged robots'. Here robots seem to be more controversial tools than other technologies in for instance healthcare (telecare, ICT, social networking, not

12 This is similar but distinct from a related subfield, machine ethics, which deals with the possibilities of moral machines and their behavior.

to say these technologies are free of controversy) because of their prior and parallel status in popular culture *(see 8.0 Imaginaries)*. Robots are not merely objects of the laboratory, but also of screen fictions and literary tales (Richardson 2015; Reilly 2011; Reichardt 1978; Breazeal 2002). For Europeans and North Americans, robots are not neutral cultural objects but are presented in popular culture as threatening and disturbing (Richardson 2015). These disturbing perceptions of robots are not helped by recent surveys that suggest robots and automation could put half of the world's population out of work (Yuhas 2016) which is also a concern in roboethics.

On the other hand, however, efforts to systematically engage with ethical reflection and roboethics research within a robotic community continue to remain limited. This is due to a number of factors, for example the very distributed nature of robotics research as well as developers' formal education that often leaves ethics unaddressed (except for safety concerns). It has been argued that until recently, social and ethical implications of robots have been "largely ignored" (Bekey, 2012) and the main ethical position within the robotics community was that of 'not interested in ethics' (Veruggio and Operto 2008).

Both of these claims are mirrored in the findings of REELER. However, REELER differs from most roboethical discussions by its ethnographic approach – diving deeper into the reasons why there is a gap between a community of ethics specialist and the community of robot developers.

We are not alone in emphasizing a closer collaboration with end-users and other affected stakeholders, through social scientists as intermediaries.

In recent decades, discussions on roboethics have shifted more towards the process of design, and are less interested in the individual engineer. According to Wynsberghe & Robbins (2014) two (or three, if one counts their own contribution) schools within this field can be distinguished. The first school:

"believes that ethics ought to be incorporated into research and design practices and holds a pragmatic view of ethics – that ethics in this arena must facilitate the design process rather than hinder it." (ibid., 948).

Furthermore, the advocates of this school argues that ethical reflections of this sort can and should be carried out by the practitioners themselves (Ibid.). The dominating approach within this school is *Value Sensitive Design* (VSD) (Friedman, Kahn & Borning 2002; 2006). VSD is: "a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner" (Friedman et al. 2002, 1). This is done through three different 'investigations', conceptual, empirical and technological. The conceptual investigation deals with questions such as: what do we mean by a particular value (e.g. transparency)? "Who are the direct and indirect stakeholders affected by the design at hand? … what values are implicated? … Should moral values … trump non-moral values?" (Friedman et al. 2006, 351). The empirical investigations complements the conceptual by going beyond armchair speculation and asking questions such as: "How do stakeholders apprehend individual values in the interactive context? … Are there difference between espoused practice (what people say) compared to actual practice (what people do)?" (ibid., 352) These questions are answered by utilizing the full range of empirical methods, quantitative and qualitative. Finally, technical investigations evaluates, which technology best serve to realize the value identified in the prior investigations (ibid., 353).

Other approaches, although less prevalent in the literature, within this school are *participatory design* (sometimes called co-design) (Muller, Wildman & White 1993, Spinuzzi 2005, Oswal 2014), centering on the inclusion of stakeholders into the design process, stressing the importance of exposing system designers to everyday realities of end-users. Similar in scope and purpose are the *Human-centered design* methodologies (e.g. Rosenbrock 1989, Giacomin, 2014), which emphasize the understanding of end-user needs. This involves determining the design requirements and defining design concepts based on what is known about the people involved, and what is known about the environment in which the interaction takes place (Giacomin 2014).

The second school believes that reflection on ethics in the context of design should be broader, and deeper, than engineers' training and time allow for (van Wynsberghe & Robbins 2014). For instance, through the moral philosophy that "helps engineers to interpret their responsibility and think more critically about it." (van der Burg & van Gorp 2005, 235). By the critics' accounts, such approaches are heavy on theoretical thinking, but contribute little in the way of actionable guidelines, van Wynsberghe and Robbins claim (van Wynsberghe & Robbins 2014).

Finally, the third school attempts to merge the two schools in demanding rigorous, deep and actionable ethical reflections, carried out by social scientists or humanities scholars (often ethicists, but not exclusively) – in cooperation with robot makers. These outside experts are to be part of the design process from the beginning, working closely together with engineers and contributing to the end product (van Wynsberghe & Robbins 2014). This is the youngest of the three, and currently van Wynsberghe and Robbins' 'ethicist as designer'-approach has gained the most attention, though other approaches exist (e.g. Seibt, Damholdt & Westergaard 2018).

It is with this 'school', that REELER has the most affinity. However, we also acknowledge the many issues arising when robots are developed and implemented, where experiments with robots are often ongoing. Therefore, we may need a new kind of applied ethics that relies on a new role for social scientists in development, which we call alignment experts. These alignment experts will have the sole function of enacting ethics as relational responsibility.

4.5 Ethics as relational responsibility

Our cross-case analysis has opened for a new understanding of ethics than r is currently represented by the bulk of literature on ethics and also differs from the understandings we find in the robot developers' own reflections. While the chapters in Part Two of this publication focus on novel aspects of ethics that robot makers can address and act on (e.g. working more inclusively) *(see 5.0 Inclusive Design*) to generate a more user-oriented innovation economy (*see 6.0 Innovation Economics*), we have also found an aspect of ethics that may be more difficult to deal with: as design processes are distributed so should ethics be. Furthermore, we have found that situated practices pose many new problems that are not resolved with safety regulations or guidelines (*see 7.0 Learning in Practice*).

In this last section we introduce some of our own suggested solutions to the problems we have identified in REELER. We want to emphasize that in order to raise awareness of ethical issues, we need relational responsibility for making ethical solutions in robotics, which we develop here and in the conclusion of this publication.

In practice, what matters is not only how we define and study ethics in robotics, but also how we incorporate ethics into the actual design thinking and practices. This applies as much to individual robot developers as to the community of robot makers as a whole. Robots are socio-technical systems and the robot design is always distributed among different parties involved and situated in complex physical and social contexts. In this sense, in order to pursue responsible robotics and ethical robot design, it is of course much more complex than simply prescribing rules of conduct or delivering ethical guidelines for robotics as has already been done in rich measure. The key emphasis here is on the understanding of ethics as a form of personal and collective engagement. The collective responsibility points to human persons standing on both ends of the robot design process rather than on robotic systems or safety concerns or abstract considerations detached from the actual robot design and development process.

In general, when addressing responsibility in relation to robots, responsibility has been typically understood as a matter of individual accountability for the robot conduct and errors as well as resulting harms. Given the complexity of the robotic systems (in particular their increasing degree of autonomy), as well as a distributed nature of the robot design, attempts to delineate the corresponding responsibility often stop with pointing to the 'responsibility gap'. We argue here that to a large extent, the difficulty is due to the application of the individualist tradition to the notion of responsibility and limitations that come with it.

In fact, there has been a growing recognition of the need to go beyond a narrow understanding of ethical problems in the AI and robotic systems, in particular the 'Trolley Problem' approach [13] and there is a need to embrace the totality of the social and cultural contexts robots and robotics are part of. This includes development of such approaches as for example 'network responsibility' and 'distributed responsibility' (Ethics Task Force 2018; Crnkovic 2012) and the corresponding idea that responsibility and accountability should be shared among all actors involved in the design and use of a given robotic system. We propose here to bring such thinking further to include the notion of 'relational responsibility'.

The key concept in relational responsibility is, of course, that of relationship. A traditional ideology of individualism favors the conception of the human being as an individual endowed with subjective agency and the capacity of rational deliberation independent of the surrounding social, cultural and historical context (McNamee & Gergen 1999). From this perspective, single individuals are thought to be fully responsible for their own conduct and the ability and willingness to take and attribute moral responsibility is viewed as an integral and fundamental part of the conception of the person (AI, Robotics and 'Autonomous' Systems 2018). Relational responsibility emphasizes the role of relations where "individuals are such only by virtue of their creation in relationship" (McNamee & Gergen 1999, xi). In other words, the notion of relational responsibility relies on the assumption that humans are 'relational beings' (Gergen 2011) where all the meanings and language we share, including our understanding of morality, are constructed in the course of human interchange. In this sense, relational responsibility is a result of interdependencies and connections between different actors and the entire focus shifts from individual selves to 'we' (McNamee & Gergen 1999). Since relational responsibility does not allow identifying a fixed locus of origin for what is the case (McNamee & Gergen 1999), one needs to address responsibility as a process and a particular type of engagement.

Preliminary attempts have already been made to apply the concept of relational responsibility to robotics. For example, it has been pointed out that responsibility should be understood not only in terms of responsibility *for* something but also *to* someone (Coeckelbergh 2016). In this sense, the emphasis is on the link between being responsible and being a person rather than only on what one does. Also, given a broad and inherently social frame of reference for relational responsibility, it has been argued that the concern about responsibility should inquire into the conditions that make responsible action and responsible practice possible (Coeckelbergh 2016).

13 Wikipedia: The trolley problem is a thought experiment in ethics. The general form of the problem is this:
You see a runaway trolley moving toward five tied-up (or otherwise incapacitated) people lying on the tracks. You are standing next to a lever that controls a switch. If you pull the lever, the trolley will be redirected onto a side track, and the five people on the main track will be saved. However, there is a single person lying on the side track. You have two options: Do nothing and allow the trolley to kill the five people on the main track. Pull the lever, diverting the trolley onto the side track where it will kill one person. Which is the more ethical option?

Others have emphasized the importance of taking responsibility in relation to new technologies 'as a society' (Ethics Task Force 2018) and as 'members of humanity' (Ethically Aligned Design, Version 2 (EADv2), 2017). Following the approach, according to which moral responsibility can never be allocated to autonomous technology (AI, Robotics and 'Autonomous' Systems, 2018), we propose here that relational responsibility frameworks apply to human actors only and they exclude robots as potential moral agents (this is also why the notion of 'relational responsibility' seems to be more adequate than 'networked responsibility'; the latter opens the door to inclusion of non-human agents).

One way to further develop frameworks for relational responsibility in robotics is to focus on the notion of 'dialogue' that would engage both robot makers and affected stakeholders. When addressed through the lens of relational responsibility, dialogue can be understood as a form of expression and engagement that may actually transform the actors involved in such a dialogue. Also, since the notion of relational responsibility here refers to moral responsibility in the first place, it implies the need for the development of the entire 'culture of responsibility' rather than only specific analytical methods and approaches.

In this final section we begin by developing our own solution as a suggestion to how robot makers can deal with the unresolved ethical issues around the inclusion of affected stakeholders found in REELER and presented in the remaining publication. We suggest that robot makers, as well as affected stakeholders, expand their understanding of ethics to include the relational character of how to act responsibly, and have dialogues, when developing distributed technologies. This means giving voice to people outside the 'inner circle' of robotics – and as already mentioned this is not an easy task. What is needed is people who are experts in facilitating alignment between stakeholders and robot developers to ensure relational responsibility. In REELER terms, *alignment* takes place through processes of *collaborative learning*.

In collaborative learning humans in a group cannot only learn from each other (collective learning), they can also make use of their diverse competences and thus divide the responsibilities among group members. Following Anne Edwards, different groups need to learn how to share underlying motives for pursuing a joint activity, but that does not mean they need to share their core expertises (Edwards 2010). Though collaborative learning requires all parties are equally engaged when working towards a common goal, they do not need to collectively share all the knowledge and skills needed as long as they can make use of each other's diverse expertises. The expertise of the robot developers includes their technical skills and disciplinary knowledge of design and development. The expertise of the affected stakeholders includes their situated knowledge of what matters in their everyday lives. In order to develop responsible and ethical robots together, they need the required relational agency to:

"Recognize the resources and motives that others bring to bear as they begin to interpret the common problem space (the object-motive) and 2) resourcefully participating in expanding the problem space by "aligning one's own responses to the newly enhanced interpretations with the responses being made by the other professionals while acting on the expanded object" (Edwards 2010, 14).

Following Edwards' definitions of relational agency, REELER proposes that collaborative learning can lead to relational agency, which builds on an evolving expertise where the engaged parties recognize "what others can offer a shared enterprise and why they offer it; and being able to work with what others offer while also making visible and accessible what matters for you" (Edwards 2012, 26).

However, we also recognize that this is easier said than done and thus call for a two-pronged strategy (*see 13.0 Conclusion*). On the one hand, the field of robot makers must develop a new roboethical culture that ensures robot developers take affected stakeholders into account. On the other hand, given the distributed character of robotics, the robot makers, and affected stakeholders' diverse understandings of ethics and the situated character of the expertises involved, REELER suggests a new profession of *Alignment Experts* (*see also 13.0 Conclusion*). Alignment experts must be able to help build relational responsibility. Such experts know alignment must entail a growing understandings of what matters for each group involved. The experts should be able to interpret challenges in alignment of practices and mediate a common knowledge made up of what matters for each collaborating group of people.

4.6 Concluding remarks on Ethics Beyond Safety

REELER's data indicates a need for an overall shift from safety-oriented ethics in robotics towards a more holistically oriented 'distributed ethics' and above all a 'relational responsibility' approach. A key premise is that ethical concerns arise together with, and not in addition to, engineering work and they evolve as robotics evolves.

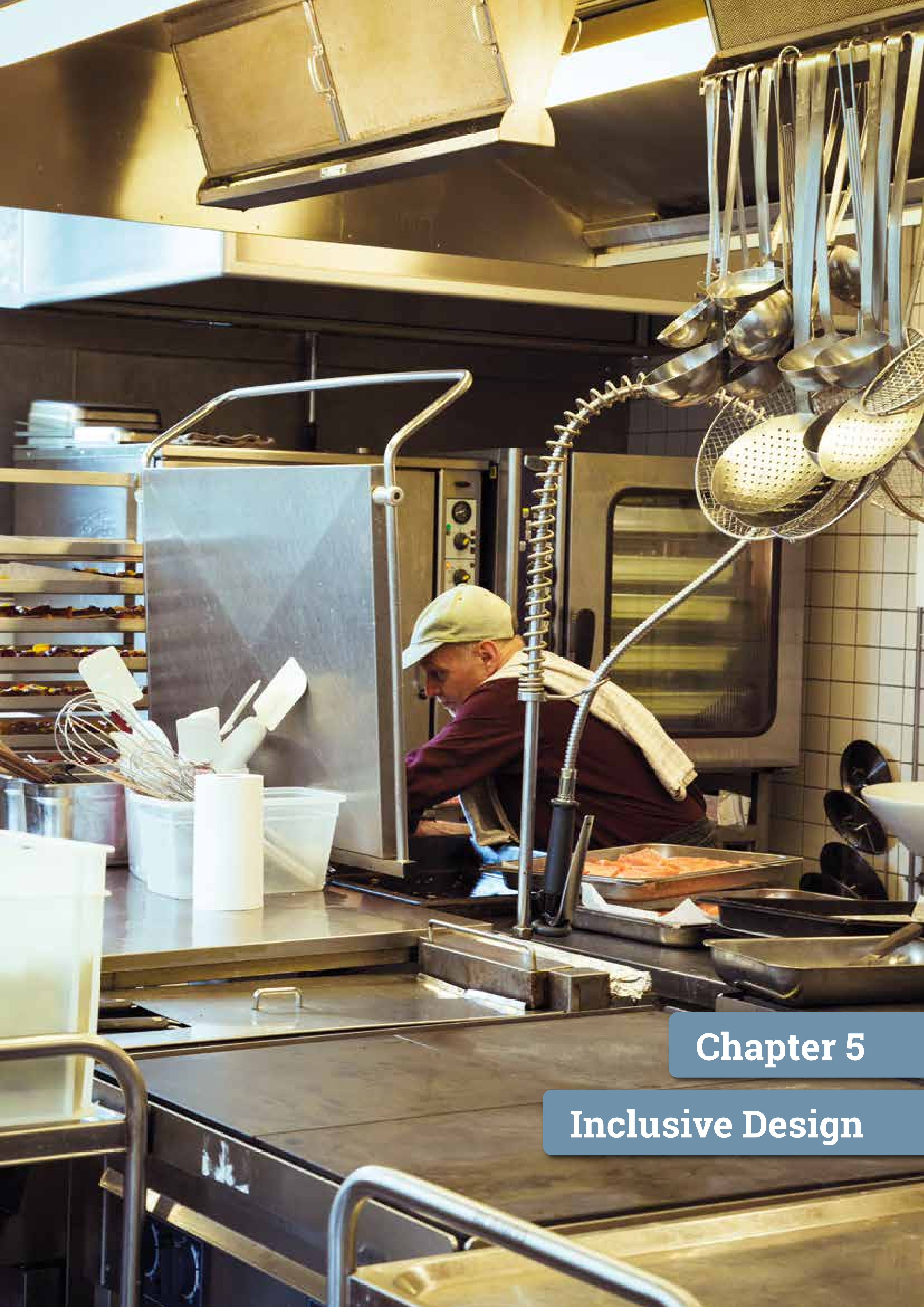
By reading across the robot makers' statements about ethics in our 11 cases, some patterns emerge: 1) the robot makers mainly see ethics as tied to problem-solving and safety as well as keeping or making regulations and standards, and 2) many have high standards and want their robots to do good, but they do not have the affected stakeholder's perspective. The expressed understandings of ethics limit the robot makers' responsibilities to making inherently good robots, following regulations and making technically safe robots. Nonetheless, despite the European Union's emphasis on ethics, many robot developers still do not think ethics is tied to *their* technical work, and rather regard ethics as tied to human aspects, which are seen as separate from the technical aspects. When robot developers do not go beyond technical safety issues directly tied to their specific products, they tend not to consider, for instance, hacking or privacy issues as ethical aspects tied to their design decisions. The ability to develop a more holistic ethics is further challenged by the fact that robot components are developed by different people in different places, which makes is difficult to build a common ethical ground around the materiality and meaningful assembly of these parts. Moreover, ethical reflection and engagement with ethics are sometimes viewed as only optional in robotics R&D or 'placed' in special departments separate from the actual development process, typically in larger companies.

Another finding is that some robot developers, as well as company owners, view humans as an obstacle to the robots' productivity and efficiency – and that their emphasis is on how humans and environments have to change to accommodate robots. REELER's research entails identifying patterns across variation, while also highlighting particular isolated findings that have great impact or import in roboethics. So, even if only a fraction of robot makers view humans as an obstacle to the robot's efficiency, it is still an ethical challenge that has not been dealt with in the academic and political debates about robots and roboethics, unlike issues of autonomy and robot rights, for example.

Yet, it is also important to stress diversity in the robot makers' approaches to ethics. Some do go beyond the problem-solving approach into a more holistic way of perceiving robots; as a technology that affects people's lives.

As our research shows, today some humans are actively prevented from participating in these debates when, for instance, their employers forbid them to participate in REELER's research. We also see that a number of developers do not engage in this topic, because they do not care about these debates. Furthermore, public debates on how to deal with ethical issues may be misplaced partly due to the lack of ethnographic research into what actually matters for robot makers and affected stakeholders, how they learn in their everyday lives (*see 7.0 Learning in Practice*), but also on the prevalent misconception of robots as more than machines (*see 8.0 Imaginaries*). These gaps between the ethics needed in an everyday-life perspective and what is found at the table of ethical experts and robot makers may be closed by the type of 'holistic' education proposed in this chapter. But we also call for enhanced human proximity (*see 12.0 Human Proximity*). As a means to facilitate this proximity, and to help affected stakeholders' and robot makers' collective engagement in developing relational responsibility, we suggest alignment experts as a new type of intermediary.

Alignment experts could help affected stakeholders get access to the relatively small group of humans who today make ethical decisions and regulations, and thereby help to bridge affected stakeholders' perspectives on ethical issues of robotics with policymakers', philosophers', and engineers' ethical considerations. Another task of alignment experts could also be to work on the 'isolated' character of ethics. The overall purpose of alignment experts is to foster alignment of motives with the aim of building a new form of relational responsibility and agency in robotics.



Chapter 5

Inclusive Design

"

At first, we had a lot of users involved. But you only get the answers you ask for. The question is if you are asking the right questions.

(Valdemar, engineer and CEO, robot developer, WIPER)

◀ Inclusive design entails reflecting on real persons in real environments. (Photo by Kate Davis)

5. Inclusive Design

How to avoid excluding potential users?

You will find here

- Overview of analytical frameworks for inclusion and exclusion in robotics design
- Insights into how body features may exclude potential users if not considered in the design
- Insights into how unaccounted differences in cognitive ability may exclude potential users if not considered in the design
- Insights into how site-specific issues may exclude potential users if not considered in the design
- Insights into how affordability may be considered in the design
- Reflection points for inclusive design in robotics

You will acquire

- Awareness of normative thinking
- Awareness of how to identify and analyze inclusion and exclusion issues in robotics design, development, and implementation
- Awareness of how continuous reflection on inclusive design in robotics can help identify a wider range of potential users

With the rapid advancement of robotic technologies, the range of people who will be potentially affected by the introduction and use of robots also increases. Robots are no longer relegated to factories, but are found in everyday places like hospitals, homes, and even supermarkets where people of different ages, genders, nationalities, and abilities, are expected to engage with robots. In order to successfully integrate robots into everyday human physical and social environments, we must address the question of inclusion and exclusion that comes with robotization. Across sectors and robot types, REELER has found that design choices inherently include and exclude particular users, settings, or groups, and that many robot makers are not always aware who they include or exclude with their robot designs. This chapter presents common exclusion factors such as body features, cognitive ability, physical environment, and cost. Moreover, we identify opportunities for inclusion by fostering a less normative approach to inclusive design that can facilitate more equitable and accessible implementation of robots in our society. More inclusive thinking may help robot makers to increase the social acceptance of robots and to meet end-user needs, to ensure compliance with existing regulations that often explicitly promote inclusive approaches, and to ultimately produce robots that serve the public good and intended purposes.

5.1 What is normative thinking?

Issues of inclusion & exclusion in robotics may be tied to different aspects of the robot design and functionalities, as well as wider implications of the implementation or application of a given robot. A person may be excluded from the use of exoskeleton robots if they have the wrong body size, or may miss the benefits robotics technologies bring if

Inclusion/exclusion: *A multi-dimensional concept that here points to the fact that whenever design decisions are made, they involve the process of full or partial inclusion/ exclusion of individuals or groups of persons from the given dimension of the reality in question.*

they cannot press the right buttons, or may be excluded from particular social contexts that change with the introduction of robots. Entire sections of society may be excluded if a robot requires a wireless internet connection to function, or if the user must be literate in a particular language to operate the robot. REELER's ethnographic research has found issues of exclusion tied to body size and strength, cognitive ability, and physical environment. Sometimes the robot-makers become aware of these issues during their design work, but often the issues remain with the affected stakeholders. Our analysis across cases and field-sites in REELER reveals, however, patterns of unintended exclusion *and* exclusion by choice.

Given the constitutive nature of technology in our society, technology in general and robotics in particular literally transform human lives. If we agree that robots are 'a mirror of shared cultural values' (Capurro 2006) and 'robotics has a clear potential to efficiently address major concerns which affect us all',[1] then we may observe a link between the process of designing and implementing robots and the degree of inclusiveness of our societies. To include something is to make it part of a whole. However, this whole will always stand in a relation to what is outside. Inclusion is a multidimensional rather than a binary concept: An individual or a group of persons may be included in some dimensions, but excluded in others. Our aim is not to seek to eliminate exclusion caused by the design, nor do we expect it is possible to include everyone/everything all the time; rather, the purpose of this chapter is to shed light on how normative thinking tends to lead to particular issues of exclusion in robotics and to point to opportunities for adopting more inclusive robot development practices.

Inclusive design: *An approach to design that recogizes user diversity, and encourages reflection on one's own normativities to make informed design decisions that include as many of the people who could benefit from the designed product as possible.*

Inclusive design is an approach that applies to a variety of technologies and dimensions from architecture, to user experience, to robotics. We define inclusive design as the design process that emphasizes an understanding of user diversity. We stress this perspective here, because we have seen a lack of understanding of how users differ from each other and from robot developers, as a recurring theme across the cases in REELER. Inclusive design has been described as a process, a design practice, and a part of a business strategy, rather than merely a genre of design (Keates 2004). Inclusive design is a key term here because, independently of the area of application, it emphasizes human-centered approaches in design thinking and acknowledges diversity and difference as well as offers a degree of flexibility of a product.

When addressing questions of inclusion and exclusion, one should be aware of potential normative, individual, and cultural biases each person may demonstrate, whether explicitly or not. Biased thinking may lead to exclusion of specific individuals or groups. Any design approach is in fact biased, in that it targets specific groups, cultures, or applications (Keates 2002); however, inclusion and exclusion can be more or less intentional. At the same time, one should remember that inclusive design can never be understood as 'design for all' but calls for realistic goals, since it is not possible to address everyone's needs via a single robotic platform (Abascal 2005).

Normative thinking: *A type of thinking where a group of persons develops specific implicit assumptions and conceptions of reality ('norms') and believe that all other individuals or groups naturally should accept these.*

Biases need not be prejudices. As noted by the gender researcher Londa Schiebinger, when seatbelts are designed in a way that they fit most men and not most women: "This is not about active discrimination; the bias is largely unconscious" (Schiebinger 2014, 9). It is simply taking what is self-evident from your own body and world-perspective and framing that as the norm. Particular examples of **normative thinking** can also be defined as implicit biases that may underlie robot makers' work. In general, normative approaches imply developing and following specific assumptions or conceptions of reality without engaging in empirical investigations that could verify a given assumption or require going beyond one's own individual or group perspective. Uninformed, or over simplistic, views of end-users and affected stakeholders' needs and wants can surface during the design process or after implementation. An inclusive design approach is important in robot development because unreflected implicit biases may lead to exclusion of potential users or reduce the uptake of the robots if the exclusion only appears after attempts to implement the robot where adjustments are no longer possible.

In the following, we identify and present four main examples of unintended exclusion relating to: 5.2 Body features, 5.3 Skills, attitudes, and abilities, 5.4 Physical environments, 5.5 Resources, and 5.6 Gender. Next we move on to 5.7 Alternative solutions and end this chapter with section 5.8, in which we summarize and offer some recommendations.

5.2 Body features

The following section provides examples of what inclusive design challenges may look like in practice. One of the examples comes from REELER's analysis of healthcare robots. Trends in healthcare go in the direction of more freedom for patients to choose where they want to receive healthcare. Thus, in the future, it is possible that rehabilitation centers may compete for patients. Drawing a parallel from Abrishami et al. (2014)

1 https://ec.europa.eu/programmes/horizon2020/en/h2020-section/robotics

The inclusion of actual users into the design process can reveal the exclusionary effect of normative decisions and the resulting design on intended users. (Photo by Kate Davis) on the Da Vinci surgical robot,[2] it is possible that new exoskeleton robots and robotic training machines will contribute with the 'advanced care', 'knowledge exchange platforms' and 'competitive advantages' that make rehabilitation at home a better choice in the healthcare system than rehabilitation centers. Ethical challenges may arise if disadvantages of robotic rehabilitation become eclipsed in the decision process, and robotic home training is offered as an option for all without taking user diversity into account. The same goes for all kinds of robotic devices intended to help people in their homes, e.g. FAR (feeding assistive robots) (*see Nickelsen 2018*).

The robot developers we have interviewed in healthcare robotics often collaborate with rehabilitation centers and hospitals and in such controlled, clinical test settings where the robots often work as expected. In one case, intended users are selected for a variety of disabilities and are helped in and out of the robotic skeletons – while aided by researchers and physiotherapists. Yet, even in these controlled settings, we see that unforeseen problems with body sizes occur. When we later visit affected stakeholders in their homes or at rehabilitation centers and hospitals, they tell us how some of the robots they had looked forward to using do not meet their needs – at times due to diversity in body features such as size, strength, shape, and height.

Several of the robots studied in REELER's research indicate how normative understandings of the size of the end-users' body parts result in robot developers designing a robot that was not fully suitable for the targeted end-user group. For example, when observing actual patients and therapists using a rehabilitation wearable robot (exoskeleton) in a hospital setting, it proved difficult to make the robot fit one of the patients, because she had short arms. In other sessions with physiotherapists, nurses, and doctors from other hospitals, they discuss how people with long or short arms might have problems fitting into their older generation rehabilitation robot, which they therefore consider discarding.

Thus, even though these rehabilitation robots are built to be adjustable, the degree of adjustability was in this case not sufficient or adequately conceived to accommodate different types of human bodies (*see Nickelsen 2018* for more examples).

This example illustrates how design decisions based on normative assumptions rather than empirical observations of end-users' physical characteristics can lead to potential exclusion (and disfavor) of users with 'non-standard' bodies. This is not only an issue in healthcare. Across several REELER cases assumptions about the user's body size came into play while we visited robot developers working on prototypes. In the case of an educational robot (ATOM), the developers see children as their target end-users and design a robot to be operated by a remote controller. However, at first, the robot developers design the control panel to fit the hands of their test person – which was one of the robot developers. Nevertheless, this case also provides suggestions for how to successfully manage normative design assumptions and related risks of exclusion. In fact, the robot developers in charge of designing the educational social robot were well aware of the risk of being biased and normative when designing devices from their own perspective, instead of that of the end-users. Therefore, when developing the robot interface, they took steps to acquire a child's perspective and involved children in different phases of the robot design and development. Through the tests with kids, the robot developers realized they had initially designed the control panel to fit the thumbs of adults and not the much smaller hands of their actual end-users. A necessary adjustment was thus made to fit the size of children's hands.

> *For example, when designing an interface, the programmers as adults have bigger thumbs than children do, right? It is such a silly thing. And they [developers] just design it to make it comfortable for themselves. And then we go to the kindergarten and it turns out that a 4-5-year-old kid has thumbs that are so small that he/she cannot reach to the left, right? For example, to make the robot turn left. And such things just had to be done, to know what the child would do, what limitations he/she has.*
>
> (Leon, Robotics start-up co-founder, robot developer, ATOM)

In another case (WIPER), the hand-size of the end-users is also a concern of the robot developers designing a construction robot. They discovered that one of the robot's selling points could be that women, who hitherto rarely took part in heavy lifting work in construction, could take part in construction work with the aid of the given robot. This robot too ran into problems as the developers only gradually acknowledged the need to accommodate persons of different hand-size when designing the controller.

In the case of a cleaning robot (SPECTRUS), the robot developers did a good job trying to accommodate their design to include different body types. However, when implementing their cleaning robot internationally, it turned out their design of docking a tablet on the doors of the hospital had been measured according to Northern European standards (tablets are essential parts of this robotic system). In the course of design and development, the robot developers had come up with an over-the-door hook for docking the tablets, and had deliberately made the hooks to accommodate short persons. However, they envisioned short European persons. When the robot was implemented in a country outside of Europe, the hooks turned out to be too high for the users to reach. In this

2 A robot developed to assist a surgeon during operations.

sense, the design of the robotic system (hook length vs body size) comes to unintentionally exclude certain places and people from using the robot.

As mentioned a point that cuts across cases is that the type of people we name ‘directly affected stakeholders’ are often not considered in the design processes. Within healthcare robotics, directly affected stakeholders include, for instance, a husband who has to help a wife with one-sided paralysis fit into an exoskeleton robotic device, or the professionals who work around the robot without it being thought into the design. Pointing back to body size, one therapist addresses the work space around a robot in a hospital setting. When using the exoskeleton, it was difficult for her to work around the robot, because it took up much of the available work space. The narrow space left to operate in caused discomfort to the therapist working in direct proximity of the robot:

> *Well, I think it takes up a lot of space. So, even for me, my breasts are squeezed. You don’t have to be particularly large and have breasts or anything, it is simply too large.*
>
> (Nina, physiotherapist at a hospital, affected stakeholder, REGAIN)

While body size may seem to be a relatively well-known factor in robotics design, REELER’s research shows that it continues to raise new inclusion and exclusion challenges. Body features are not necessarily related to the age or gender of a person. However, as a starting point robot developers could reflect on how these aspects may influence the human body and should be considered as early as possible in the design phases. The same goes for other body issues such as disabilities. It is also a finding that robot developers often overlook the body issues tied to directly affected stakeholders even more than they overlook the body size of the end-users. Robot developers could improve design and uptake of robots by paying attention to the staff, the relatives, and other directly affected stakeholders, and how they (and their bodies included) can be thought into the design of a given robot.

5.3 Skills, attitudes, and abilities

In clinical trials, patients with difficulties in understanding the instructions and forming the required intentions to act are often excluded from testing new robotic equipment (as we saw in several REELER cases). This can pose a problem from the point of view of the affected stakeholders, if for instance the robot offers home training with exoskeletons for patients who, following a stroke, can no longer read a manual. Two affected stakeholders (Britt and Nikoline, physiotherapists managing robot-tests, REGAIN), for instance, emphasize that they often meet patients who cannot use the offered robot technology in their work with rehabilitation because the patients have suffered strokes or the like and therefore may also have impaired cognitive abilities. For them, the issue of cognitive ability becomes relevant when developing robots for home training. Here, too, attention to their work (as directly affected stakeholders) entails that the staff has to know how to deal with this circumstance. However, other types of cognitive issues may also result in people being excluded from the potential benefits of a given robot. It can be workers, who do not have the right education or literacy skills to understand how to operate a robot when implemented, or for reasons of age or ability struggle to adapt to the new robotic workplace (*see also 6.0 Innovation Economics, 9.0 Economics of Robotization, and 10.0 Meaningful Work*).

> *When we went from horse carriages to cars, what about all the people who took care of the horses? Well? There’s an ongoing development and you can’t really stop it. And that’s everywhere in our society that there are developments. If you’re not a part of that, well, then you have to figure something else out or change your mind and be a part of it, right. And it will probably be the older generation who will be left out, because it’s like, should I spend the next four years studying to become an industrial technician, right?*
>
> (Viggo, safety and work environment coordinator, affected stakeholder, WIPER)

When developing robots, robot makers usually have a specific group of end-users in mind and these are often perceived according to the robot developers’ own expectations (for instance having the same height or the same technical understanding as themselves). They may therefore lack consideration for how humans in reality differ from how they are perceived. It can make a difference how people’s attitudes and capabilities related to the use of robots will fit into the bigger picture of intergenerational frameworks. Introducing robots to new sectors may sometimes bring rather unanticipated consequences for intergenerational relationships. Many robot-developers believe, especially in the ATOM-case with the educational robot, the current generation of children are born as ‘digital natives’ and therefore often have a better knowledge of interactive technologies than adults do, as well as a greater ability to learn how to use new technologies. This opens for robots creating an exclusionary processes as a new split between adults and children. If it is true that children can easily use the robots - what happens if the adults, e.g. parents or school teachers, are not able to understand their use of robots and robotic educational aids? Will or should mature adults be viewed as someone in a position to teach kids? Such considerations related to the introduction of robotics in new sectors can affect, in this case, the adult teachers in ways that question their knowledge, skills and relations to young learners.

> *[A]nd then there is also the fact that children have a little more knowledge, know what they are talking about as if the roles changed, that the children are teaching adults, get adults interested, and the adults must look for that knowledge, right? If they want to have a discussion with their child.*
>
> (Amelia, head of orphanage, affected stakeholder, ATOM)

In the case of the educational robot ATOM, the robot developers chose to address this potential exclusion of mature teachers by making a design that involves more than one user and requires interaction between children and adults.

> *In the case of our robot, I hope to introduce even a multiplayer task where two robots are needed. This way we do not just do it on the tablet, but we have to find a partner who also has a robot to complete the task. The second type of task that we considered really important is one task that requires interaction with an older person. So, the difficulty of the task will be set so that the child is not able to do it himself/herself and must go to ask for help, I do not know - mom, dad, brother, sister, anyone. They will not stop the story itself, but they will be given special rewards.*
>
> (Erwin, university psychologist, robot maker, ATOM)

However, research has shown that the robot developers may be wrong if they assume young people are automatically included in their design (Facer and Furlong 2001). When children and young people seem better at using technologies it is not because of a deeper understanding, but because they are more used to having these technologies around. It is not so much a matter of age as of familiarity and understanding of technology (Eynon and Geniets 2015).

Despite familiarity, many stakeholders, for instance workers in industrial production companies, do not understand the digitalization and digital processes behind these devices and their repercussions, despite being familiar with a given technology:

> *The old Baby-Boomer maintenance workers are coming and saying: 'Hey, the tablet, that's nothing new. I already know everything.' So, I say that he does not know everything, because, what is behind it all? Do you know what data is recorded? Do you know that there is a knowledge database behind it all?*
>
> (Frederikke, work council representative, affected stakeholder, COBOT)

Not understanding a robot can also come down to basic dyslexia, as seen in some cases (REGAIN and WIPER) where reading a manual is a prerequisite for using the robot. When developing and delivering new robotic systems, it requires providing adequate training to affected stakeholders. The problem is, however, that the training is often provided to an only limited number of direct end-users and the assessment of training needs is inadequate. For example, in order to implement construction robots, there is a legal requirement to deliver an instruction of use along with the robot. Such instructions often take the form of manuals to be read by construction workers before they use the robot. Yet, it turned out that for various reasons, such as dyslexia or language barriers, some construction workers are unable to read the manual and are hence (legally) unable to use the robot.

> *A construction robot requires an instruction and according to the law it is required that we provide such an instruction whenever we introduce a new tool. And we do that. Well, in theory because actually it is the technical equipment rental business which distribute them, who have to provide a manual for each tool. So, they describe how it should be used. The craftsmen then have to read it and at that point it is important to remember that there is actually some of them who cannot read! That is an issue. We have some craftsmen who are extremely dyslexic. They get along, of course they do, but you tend to forget that they cannot read a huge manual. They just can't read it.*
>
> (Joan, union representative, affected stakeholder, WIPER)

This example illustrates how ethnographic research can unfold end-users' real life preferences and needs that are not taken into account when simply assuming, based on normative thinking, that written instructions are the most suitable form of training.

In a different case, COBOT, training is provided with new technologies but is limited to only small groups of highly skilled employees. Hence, the implementation process excludes blue-collar workers, and large groups of the workers are deprived not only of adequate training in how to understand the technology but also acknowledgement as employees. Robot developers in collaboration with robot facilitators, such as policymakers, could diversify training strategies to include a holistic approach that would allow to include a variety of groups in the training process, from operators, to managers, to directly affected stakeholders (i.e., workers who may not be operating the robot but are still affected by it). For the latter group, it may require expanding their knowledge and understanding of the process of robotization taking place at the workplace. To give an example, in order to recruit a new type of operators who are willing to work with robots at the construction sites, the staff of HR departments may also require robot-related training. If training and literacy are not provided many workers may be excluded from operating robots.

Finally, whether affected stakeholders understand a robot well can depend on the types of expectations, visions and ideas they hold about robots and what types of alternatives they are offered. Though it may seem inaccurate to list these as skills, REELER has found examples of people being excluded from the (potential) use of robots due to their lack of knowledge, and maybe even fear, about robots. Here the notion of technological literacy becomes relevant (Hasse 2017). People with no technological literacy may be not able to, or even want to, use robots. As argued above, many robot developers assume these problems are solved, when younger generations grow up.

Interviewer: "Did you see some resistance?"

Simone: "Of course – the older operators that are not used to taking a laptop in their hands, they want only to finish their career in the company using manual tools but without any informatics stuff. With the younger ones, they are more, okay, used to using smartphones and the new technologies and they immediately took the opportunity to empower themselves using this robot."

(Simone, sales manager at a robotics company, robot maker, OTTO)

Some older people may feel insecure, but others have formed new routines though adequate training (*see 7.0 Learning in Practice*). Moreover, resistance to learn about new technologies and to change existing work routines may not be tied to a mere lack of particular skills nor simply reduced to a matter of age, as some robot developers tend to do:

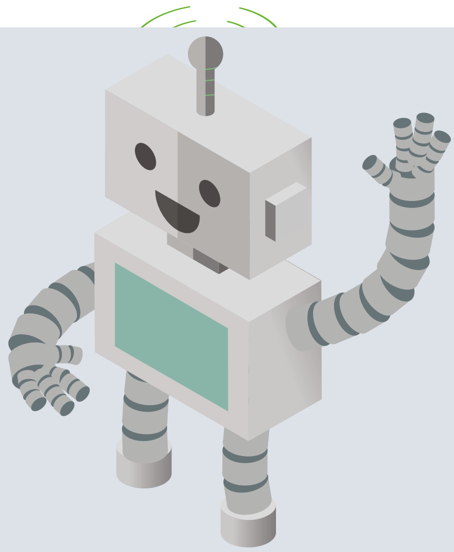
It's been changing because not only [our company] but also other companies are developing so many robots, so many automatic robots that can help people. Also there are younger people in companies, public companies, in the railway management – the mind, the approach of these guys is a little bit open. More open than the other people, than the oldest people.

(Charles, software engineer and manager, robot developer, OTTO)

It is a question of habits and it is related to the issue of changing one's old habits and that also means, the younger workers are much better to do so because they are not afraid of new technology. The older ones are a bit afraid. I would say they are. They are a bit, argh, does this actually work? We have done the job in this way for the past 30 years and that is much faster. That is the thing about changing one's habits.

(Agnes, regional manager, affected stakeholder, WIPER)

Contrary to these fast-held opinions, we find in REELER's data young people such as cleaning ladies in Portugal or farmworkers in Spain with very little technological literacy and training. Likewise, we find elderly people (among them engineers) with a lot of technical experience and an open attitude toward technology. Therefore, it is important to focus on affected stakeholders' variation in experience, rather than using age as a marker for predicting attitudes toward technologies. From the robot makers' perspective, it is important to note that end-users' engagement in hands-on practice, maybe paired with help to read manuals, may improve their understanding of robots. Emphasis on technological literacy may change their attitudes towards robots and in the end help implementation of robots considered beneficiary for work in the local settings. From REELER's data, we've seen that technology apprehensive users develop more accepting and realistic attitudes toward robots from real-life experiences with actual robots in use (*see 7.0 Learning*).



STORY FROM THE FIELD:
Multidimensional inclusion challenges

One REELER case WIPER includes a robot intended to be used at construction sites to help installing heavy doors of up to 100 kg, thus relieving workers of heavy lifts. Another purpose was to make it possible for smaller persons, such as women, to work with mounting doors, by operating the robot though a remote controller. Some of the critical design issues were discovered early enough in the design phase to make changes. For instance, the original design of the robot control panel only fitted a particular size of operators' hands, namely big male hands. Due to the lack of flexibility of the control panel, any male or female operator with smaller hands were excluded from the use of the robot. This was remedied by building a remote control with less space between the buttons. But Hans, a worker at a construction site testing the robot, explain that despite the improved design, many of the workers do not want to use it:

"I think anyone can do it [use the construction robot]. But having said that with everything new comes also people who say: "Argh, we don't want to use it, we are not used to do it in such a way". I mean, it requires that you, mentally, are willing to change yourself and then use it. If we are to work in accordance with the work requirements, then we are not allowed to lift [heavy doors] and you are required to use the machine. It may take some training and something, but the longer you have it your hand, it only becomes easier. That's the way it is with everything new."

In its 'almost ready-for-market'-stage (TRL9) it becomes clear the robot is not so easily implemented. During testing many workers felt the robot did not adapt sufficiently to their (human) pace, habits or monetary situation.

Werner, an operation and production technologist, recalls the situation:

"There was a lot of, argh, but the robot drives very badly and we cannot use it. We experienced that a lot. They [construction workers] were supposed to use it and we had spoken to the manager over there: "Yeah, they have used it and mounted the door with it", he said. Okay well, that's good. Two days passed and then we spoke with him again. "Argh, they thought it drove strangely so they just put it aside. They don't want to use it anymore". Okay, I said, we'll come and pick it up. That was on a Tuesday and we were to pick it up on Thursday. When we arrived, the construction workers told us that they had not used it at all. They had tried to mount a door with it, but it had made some trouble so they just gave up. And so it had just been left unused. But at the other sites when we arrived and stayed there from Wednesday to Friday. The first day, we drove with it and mounted the doors so that they could see how it worked, and on Thursday, I drove with it once and then they drove with it and mounted six or seven doors. And he [the construction site worker] actually got a sense for it. It was still not superfast because he was careful, of course, but he got some sense of how to do it and they actually thought it was an okay product. He just thought it was difficult to do it fast. They could do it faster themselves so therefore they would lose money if they were to mount doors with the robot."

Werner's recollection well-illustrates that inclusive design requires approaching the implementation of robots as a situated process. The key element in this process is to take a human-centered approach and directly engage with the end-users to understand their underlying motives for using or not using a robot. Implementation also entails adequate training in understanding how the robot works and the benefits it may bring, as well as giving end-users time to familiarize themselves with the robotics technologies and acquiring a sense of ownership over their work while using the robot. Without this, the process of robotization is most likely to fail.

So, why is this robot mothballed at some construction sites? In part, because the implementation process is not human-centered. The workers who had another human to show them how to use the robot, are more prone to use it than those following a manual. But part of the reason for the robot's abandonment is also that the robot works satisfactorily in the laboratory, but not in the situated environment. The workers feel they cannot use the robot, because its design does not match their actual work life. Consequently, the robot developers face resistance among the construction workers towards the robot. This resistance emerges because the underlying motives of the workers are not aligned with those of the robot developers. In principle, the robot can be applied to some types of doors weighing up to 100 kg. This turns out to be a serious limitation for the construction workers, who often need to install steel double doors that are much heavier than 100 kg. Also, depending on the construction site, workers have different amount of space available to work with the doors, which also includes very narrow passages. In order to successfully work within such spaces, a construction process needs to be carefully planned and adapted on a case by case basis. The robot cannot offer a sufficient degree of flexibility that allows adopting it to all types of spaces if it was not already incorporated in the planning process.

Werner also mentions that the workers *"would lose money if they were to mount doors with the robot"*. Many construction site workers are paid a piece rate (where their earning is based on their productivity), and keeping a high pace is thus crucial. Although the robot can relieve the workers' backs, they are not motivated to use a robot that is too slow to keep up their income level.

(Based on interviews with Herbert, construction site worker, and Werner, operation and production technologist, WIPER)

The above story from the field illustrates the complexity of inclusion challenges and the need for alignment experts (*see 13.0 Conclusion*), who can explore underlying motives and suggest relationally responsible dialogues (*see 4.0 Ethics Beyond Safety*) around the multidimensionality of design challenges.

5.4 Physical environments

When discussing inclusion and exclusion challenges related to physical environments, robots that have been designed to be used 'uncaged', outside of protected industrial environments (i.e. in agriculture, in healthcare, in private homes, etc.), are particularly interesting. This is where the embedded nature of robots shows itself as a particularly situated problem. Robots are both physically and socially embedded, i.e. connected with their local physical and social environments. This is a new development from the industrial robots that were 'caged' or 'enveloped' (Floridi 1999) in cages built for the very purpose of having robotic machines. With the 'uncaged' robots, new design challenges appear, and here robot developers' normative understandings of the sites where their robots are going to operate really matters.

For some designers it leads to reflections on how to adapt robots to, for instance, private homes, but in many cases the adaptation is reversed. Due to the variety and complexity of human environments as well as technology constraints, it is impossible to build a generalized robot that fits into all existing human physical environments. Therefore in an attempt to create 'robot inclusive spaces' (Elara, 2013), a priority is sometimes given to robot requirements and not human needs, with significant adaptations required to be made on the human side. Yet, some argue that whether the introduction of robots requires modifying the existing environments depends on the robot application:

It might be you don't have to do anything. You know, it might be the robots just fit into your existing infrastructure and require no modifications or it may require that there are certain parts of your facility where things need to be moved or more space needs to be generated. It really just depends on the application.

(Danny, sales manager, affected stakeholder, WAREHOUSE)

When investigating the suitability of robots for human physical environments it is important to remember that an important constitutive part of such environments are of course humans, who have themselves adapted to local environments (for instance growing vegetables on steep hilltops, building bridges to access them, etc). This has direct implications for how a given space is arranged and what type of design challenges it poses, and it requires taking culturally situated perspectives into consideration. Here robots, as of today, are much less flexible in adapting – and require environments that allow the robot to move unhindered with no steep, crocked pathways or annoying obstacles.

Building on the robotic concept of enveloping, Professor Luciano Floridi defines "ontological enveloping" as the process of adapting the environment to the robot to further enable its performance:

"Industrial robots have deeply affected their working environment in order to make possible their successful interactions. The industrial architecture of robotized factories is very different from that of 'human' factories. This is reasonable. The more compatible an agent and its environment become, the more likely it is that the former will be able to perform its tasks efficiently. The wheel is a good solution to moving only in an environment that includes good roads. Let us define as "onto-

Robots are often developed for use in 'robot inclusive spaces' which demand the transformation of existing dynamic work environments. (Photo by Kate Davis) *logical enveloping" the process of adapting the environment to the agent in order to enhance the latter's capacities of interaction*." (Floridi 1999: 214)

Floridi states that in recent years, robots are now enveloping the environment and creating an artificial intelligence-friendly infosphere, thereby blurring the distinction between reality and virtuality [3] as well as the distinctions between human, machine, and nature.[4] What we see across cases in REELER is a kind of to and fro of who should adapt to the everyday environment: robots or humans. In some cases, like WIPER, the workers exclude the robot because it does not fit with the messy and disorderly construction site. In other cases, like SANDY, the farming robots can only function if the environment is changed to fit it. This entails changing the way of farming, from, for instance, small farmers growing olives on hillsides to ordered plantations demanding different kinds of irrigation and ownerships. The introduction of robots may therefore be a problem for some farmers, who do not have the right size and shape of fields.

Maryse: "Yeah, they [robot developers] would like to have the crops growing in one line. Um, but then you have the moving [robotic] systems, where you have one fixed row, but that costs a lot, and you need to adjust the [field] a lot. It costs a lot [for the growers]."

Interviewer: "Okay, so what you're saying is that, the ones that developed the robot, they would like to transform the [field site] more than it is now, to make them different, where the growers would like the [field] to stay the same way? And the robot developers think it's easier for them to make the robot, if the environment changes around the robot or?"

Maryse: "Yeah, because we can harvest more crops [that way]."

(Maryse, application expert, robot maker, SANDY)

In this case, we go from a system based on 'the human way for harvesting crops' to a system based on 'the robot way for harvesting crops'. Following this line of thinking, Floridi writes:

"*… we have not yet been capable of transforming tasks, which would require our kind of intelligence to be performed successfully, into stupid tasks that a robot may safely take care of, no matter whether they do them less economically than we would (e.g. the washing-machine) or even better than we do. On the one hand, there is a need to rethink the methods whereby the same result can be obtained via different processes: consider how differently from a human being the washing machine operates. On the other hand, we need to transform the environment in which the task is performed and adapt it to the robots' capacities. Only when gardens are shaped and modified so as to make it possible for a robot to cut the grass, and streets are constructed to allow robotized buses to travel fast and safely will the relevant robots become a commodity. It is the environment of a robot that must become a bit more artificial, a contrived micro world in which objects, properties, relations and events are as narrowly and explicitly defined in advance as possible."* (Floridi 1999: 212)

If we take these issues even further, we can see that many of the uncaged robots studied by REELER exclude certain types of environments unless the environments are transformed to host the robots (e.g. SANDY, WIPER, REGAIN, and SPECTRUS). One example is a healthcare robot running on wheels and meant to operate in private homes. It has difficulties going over the thresholds in doorways found in many houses. Likewise, in a construction site, only when the sites are shaped and modified so as to make it possible for a robot to enter the construction area and move freely, will the robot become a viable product. Some robot developers see it as a future design challenge that we, humans, need to transform the environment in which the given task is to be performed by a robots and as such adapt environments to the robot's capacities – if we want robots to be included. This aspect of inclusion and exclusion is not only relevant in relation to physical environmental spaces, but also in relation to ontological enveloping of nature – as also plants and trees may be modified to accommodate robots functionality. For example, in agriculture, there is a history of breeding plants with particular properties that make them more suitable for machine picking, automated sorting, etc. This is something we've also observed in the agricultural robotics case (SANDY).

The process of enveloping may result in other design challenges. In several of our cases, the robots are considered 'generalized' robots, but through in-depth REELER analysis it appeared they are made for specific Western European sites (e.g. SPECTRUS, SANDY, WIPER, COBOT). Consequently, they will run into problems if applied in Southern parts of Europe. The main obstacle for inclusive design is the robot developers' normative approach to the environments they are designing the robot for, without being aware of the implications of the normativity. The following a robot developer explains that one expectation tied to their public funding was to make a robot for all of Europe:

3 Floridi discusses also how ICTs (Information and communications technologies) have become not only tools to interact with the world, but also environmental forces actively creating and shaping the planet as well (Same point is made in the ATOM case).

4 https://www.oii.ox.ac.uk/videos/enveloping-the-world-how-reality-is-becoming-ai-friendly-luciano-floridi-keynote-at-pt-ai-2013/

> *Interviewer: "So when you apply for a project, then you will apply for [your own country]?"*
>
> *Espen: "No, I think you have to apply for the whole of Europe. Yeah, you have to. But of course, one of the aims of a European project is having interaction and knowledge exchange between the countries. So if you apply for something which is only for [your own country], yeah, I think the chance of getting on is very, very little actually."*
>
> (Espen, senior researcher, robot developer, SANDY)

Despite the acknowledgment that European projects are meant to benefit the whole of Europe, the developers later admit that their robot is not transferable to other national contexts. Diversity in physical environments means some places are characterized by large, regular and flat spaces in buildings, construction sites, or agricultural sites, while others are full of stairs, small uneven rooms, or irregular and hilly agricultural lands. Such variation significantly affects the degree of structuring and automatisation of a given space. In the case of SANDY, the robot makers assume the robot will be suitable for a variety of environments across Europe when designing their robot. Yet, contrary to the expected, the robot is in fact designed for Northern European landscapes, and REELER participant observations in Southern Europe find that the robot would not be able to operate in those environments. In practice, it will be impossible to implement in environments that are less structured and less technologically developed than that of their home country.

Normative thinking about the environments in which the robots are expected to help with cleaning, harvesting, or construction turns out to exclude specific places, groups or individual end-users, companies, and countries from using the robots. Following their own normative understanding of space, the robot developers remain unaware of the physical challenges tied to the diversity of the environments. The examples of the harvesting and cleaning hospital robots display the huge complexities of inclusive design. Even when there are attempts toward inclusive design in robotics, the normative thinking may prevent robots from wider use. This can mean that the robots are excluded from use in huge areas: While adjusting the hook for an iPad is relatively easy (as in the SPECTRUS case), adapting a harvesting robot to the specific agriculture conditions across Europe, or even preparing it for use in other regions, requires redesigning significant parts of the robotic systems.

5.5 Resources

When considering the risk of exclusion, another issue that needs to be addressed is resources. Robots tied to healthcare such as REGAIN and SPECTRUS will presumably be implemented in hospitals, elderly care homes, rehabilitation centers – and even in private homes. Given that the financial resources for healthcare, including rehabilitation and home care, are limited, it can become a societal ethical issue whether the investment in robotic rehabilitation and cleaning will draw financial and therapeutic resources from other types of healthcare facilities and thus favor certain well-to-do groups of patients.

Depending on the robot and the area of application, the price of robots may vary from very high (only affordable by big companies) to relatively low (affordable by individual persons). However, given the novelty and complexity of robotics technologies, robots are, as yet, often too expensive for many companies as well as individual and institutional end-users to be implemented in everyday settings on a large scale. Following the site-specific issues discussed in the section above, we may expect it is often not enough to invest in the robot in itself – there should also be investments made to the environments which may be just as costly.

The cost of robotic technologies is of course an outcome of multiple factors that are only partially dependent on robot makers. At the same time, with the inclusive approach in mind, it is possible to conceive the robot design and development in a way that would make robots more affordable, and hence, accessible, for large parts of our society, with the benefit for robot makers themselves. And some robot developers are really keen that their robots are affordable for everyone:

> *It's not just working for giant companies who really can spend millions on automation. Our idea is affordable robotics for people.*
>
> (Alph, robotics start-up founder & CEO, robot developer, WAREHOUSE)

A good example coming from REELER's research is humanoid robotics. In general, there is a variety of potential applications for humanoid robots with no single area of use. However, given the cost, novelty, and complexity of humanoids, it is not clear who is the best candidate to become the early adopter of such robots. One of the robotics companies that produces humanoid robots for both commercial and research purposes has implemented an interesting strategy for development of its robots: While starting from full-size humanoids, over the years, the company has developed different platforms, gradually adding the models that are relatively far from a realistic humanoid form and function. This can be interpreted as an attempt to simplify its robots and reduce their costs, and hence make them more accessible in the market.

> *For most of the solutions, you don't need the full humanoid, so then the company started to, in some cases, just remove legs. So, the thing is they start with the full humanoid. After the full humanoid, they have the humanoid without legs. After the humanoid without legs, they have the humanlike mobile platform. That is trying to keep it as simple, with only one arm, with everything to try to reduce the cost. For different applications, and also to try to achieve an affordable solution to the market.*
>
> (Pedro, HRI researcher at a data company, robot maker, BUDDY)

A different scenario is that of implementing robots for public robot buyers. For example, depending on the design and teaching approach, educational robots may be used as single- or multiple-user platforms at school. In fact, for one of the educational robots studied in the REELER project, many tasks have been designed in a way that they require two groups of kids and two robots to engage in a game. These robots are expensive and most schools across Europe cannot afford buying more than a couple of these robots. However, also across Europe we find privileged schools, with private or public funding available, who may purchase a robot for every student. Within a country, it may be an issue of differences between public and private schools; however, there is also inequality found in how much different European countries can afford to spend on technology in education. Each time robots involve public buyers and possibly subsidies, it will be a question of who to support and based on which criteria.

> *It depends on the school; how it wants to conduct classes. Recently, I have been working on a scenario designed for a larger group of children, so that every child has his or her own robot. It was more probable that the school would buy, I do not know, 2-3 robots per class, rather than buying robots for the entire class, like 25 or 30 robots. Our assumption was to develop most of the scenarios for groups, that is there would be 3 robots used in the class, but we came across several schools that bought robots for every child.*
>
> (Monika, scenario developer at robotics start-up, robot maker, ATOM)

If the robotics community wishes to avoid exclusion due to cost factors, robot makers may consider, already in the early stages of the design process, ways of offering different purchase and rental options to private and public customers.

5.6 Gender

Gender inclusivity is a very important area of inclusive design, pertaining to normative ideas about body size, use patterns, etc. (For a more thorough discussion of Gender, please read *11.0 Gender*, available at responsiblerobotics.eu/perspectives-on-robots.) The robotics community largely consists of males. This inevitably results in gender normativity that affects robot makers' thinking about both robotic systems as well as end-users. Female and gender-diverse perspectives often remain either distorted or excluded from robotics, which is problematic not only for women and gender-diverse people, but also robotics research and the robotics market.

In general, the normative, i.e. 'ought to be' type of, thinking underlying a large part of robot developers' work is closely related to the specific character of the robotics community. As demonstrated by REELER's research, for a variety of reasons, the robotics community in Europe typically consists of men, most of them white. While this situation has been gradually changing, in particular with the increasing development of social robots and the incorporation of soft skills in robotics, the number of women in robotics is still very limited.

> *Yeah, with this move to more social areas, there are more and more women entering robotics and in this conference for instance, when the presenters are on more industrial robotics or mechanical engineering and so on, still there are 90 percent more men. But in the sessions on social robotics or service robotics, there are like 50 percent women.*
>
> (Carla, robot developer, BUDDY)

This inevitably affects robot makers' conceptions of robots, of end-users, and of reality as a whole, whether explicitly or not. On the one hand, this circumstance can blind robot makers from seeing a variety of different perspectives and possibilities that would make the design and use of robots more gender-inclusive. On the other hand, robotics also offers means to challenge gender stereotypical thinking and ultimately promote social equality in our society.[5] One example is a construction site robot in the WIPER case study. Here robot developers' design anticipates an increased number of

5 https://genderedinnovations.stanford.edu/case-studies/genderingsocialrobots.html#tabs-2

women employed in the construction industry. The underlying assumption is that since the robot relieves construction workers from hard physical work, 'strong men' need no longer be the predominant type of worker. The robot developers' expectation is not only that the introduction of this robot will make it possible for more women to work in construction, but also that robots can create new types of workers.

> *If you're thinking of mechanical robots, such as WIPER, then I think they will have an impact. I think the physical requirements for working in the field will change. Today, many jobs require big, strong men or little, petite girls. That will be evened out dramatically within the next generation or two, because physical exertion will be much less needed within industrial work. I think it will disappear, or at least diminish. I also think the requirements to operate the machines will be different.*
>
> (Valdemar, engineer and CEO, robot developer, WIPER)

One could argue that the construction industry continues to be male-dominated indeed. However, there are also other areas of application for robots where nearly all end-users are females. This is the case in the cleaning sector and primary school education, where cleaners and teachers are predominantly women. The implications of applying male perspectives to female experiences of life and work goes far beyond the mere suitability of the robot design. In order to overcome a gender bias, which will ultimately help improve the accuracy of robotics research and expand market opportunities, it requires not only increasing the awareness and study of gender issues but also actively involving women and gender-diverse people in the making of robots, both as developers and as involved affected stakeholders. (See more about the role of gender in robotics in *11.0 Gender Matters*)

5.7 Alternative solutions

Rather than being consulted and involved in the process of decision-making when robots are introduced, workers are often faced with robotization as 'fait accompli'. This is because robotization seems to be a must and whoever cannot or does not want to be a part of it will be left out. In general, technological progress and further implementation of robots often seems to be something that 'cannot be avoided'. In line with technological determinism, technology appears to be an unstoppable force that shapes our reality and the lives of individuals and of a society as a whole. While some would point to our creative and inventive nature as human beings as the driving force behind technological invention, or to the promised comforts or benefits of technological progress, REELER's data would point to pursuits of economic progress and prosperity as the true motivation behind technological development.

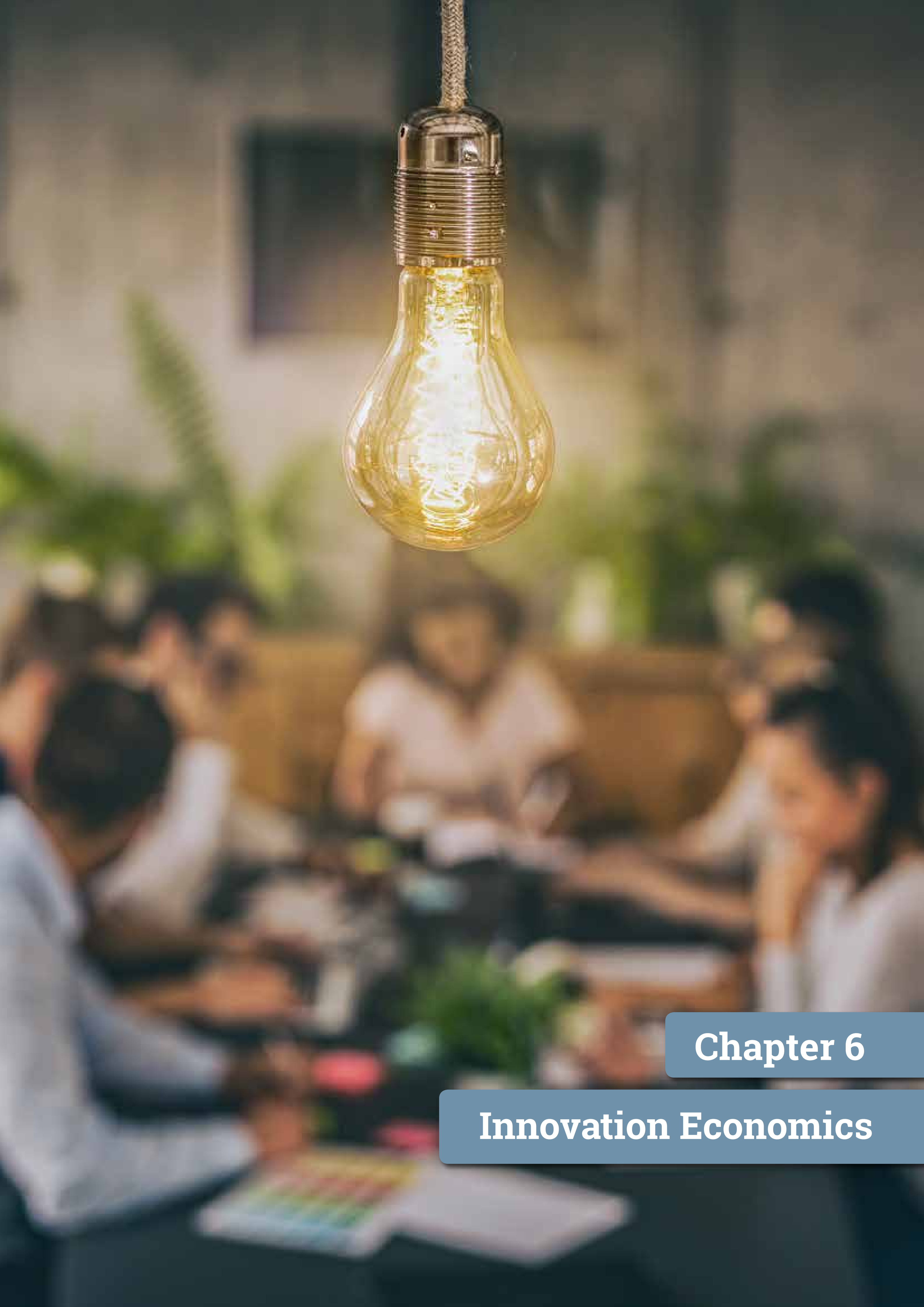
> *We live in the twenty-first century, technology surrounds us either side, we cannot avoid it. The way we use it depends only on us. So robots will be there, they will evolve even faster, they will come along more and more in our homes, they will be cheaper, they will be a better and cheaper labor force, so surely also when it comes to the labor market, they will come out and oust people, and we just have to adapt to it. We will not avoid it (laughs). If we wanted maybe we could avoid it, change history suddenly, it means development, right?*
>
> (Erwin, university psychologist, robot maker, ATOM)

From the industry perspective, automation and robotization seem to be a must rather than an option. In other words, even though it initially requires significant investments in both machinery and training, implementing robots seems to be the only way for a company to reduce the costs of production and maintain a competitive edge (*see also 9.0 Economics of Robotization*). Such an approach leaves excluded anyone who is unable or unwilling to keep up with technological developments. While some companies do consult their employees before introducing technological innovations, especially if trade unions are involved, many employees are neither asked about their preferences with regards to automation or robotization, nor given a choice for whether to comply with the changes or not. Ideally, rather than force people to use new kinds of robots, they ought to be offered the possibility to make an individual choice.

> *Well, we have to respect that you can have different opinions. We need to respect the fact that some people want to crawl up and down a lift, a scaffold, and who doesn't want to use a robot. It is the individual's choice. Some people want to dig the hole with their shovel and their wheel barrow instead of using a mechanical digger.*
>
> (Jens, CEO at technical equipment rental business, affected stakeholder, WIPER)

5.8 Concluding remarks on Inclusive Design

Part of the challenge of inclusive design is a lack of awareness of one's own normative thinking. Inclusive design requires relying on real experiences, rather than assumptions, regarding robot systems and different contexts of use. This means seeking out real implementation contexts, including physical environments and users, as early and as often as possible in the design process. Moreover, this requires reflection on one's own normative biases. However, developers often lack sufficient tools for expanding their thinking beyond the 'inner circle' of robot makers (*see 13.0 Conclusion*) to take into account the perspectives of affected stakeholders. This is something REELER has tried to address with our Awareness-Raising Toolbox, the multiplayer board game BuildBot, and the perspective-taking tools Mini-Public and Social Drama (*see responsiblerobotics.eu* and *12.0 Human Proximity*). As we have also seen in this chapter, the multidimensional challenges for inclusive design may also require closer collaborations with intermediaries, for instance alignment experts, who can call forth and translate the underlying motives of affected stakeholders and robot makers, to align these in fruitful dialogues based on relational responsibility that call forth otherwise overlooked issues of exclusion.



Chapter 6

Innovation Economics

”

Well there happens to be some conditions when you apply for such an innovation project. You need to have different stakeholders from different places. You couldn't just make an innovation project within your own university.

(Elias, university researcher, robot developer, WIPER)

◀ Innovation and technological development are the result of knowledge-based collaborations within heterogeneous networks of actors.

6. Innovation Economics

You will find here

- Overview of several perspectives on micro-level product research, development, and design
- Overview of the meso-level process of product research and development in innovation networks
- Overview of three long-term, macro-level processes of the industry lifecycle
- Empirical support from REELER cases for complications

You will acquire

- Awareness of how robot developers need to bootstrap out of the dilemma of specification sequentially in developing new robots
- Awareness of how bounded rationality and cognitive limitations have robot developers engage in develop-test-plan cycles
- Awareness of how uncertainty has robot developers engage in 'staggered expansion' of stakeholders included in defining requirements, testing products, etc.

The REELER project is concerned with identifying and creating awareness of ethical issues that may arise in the application of robots, and with providing tools to robot developers for improving the research, development, and design process of robots to increase the ethical acceptability of the impact of the application of robots in practice. Arguably, many aspects of the design are decided upon rather early on in the process of researching, specifying, and materializing a robot, but consequences thereof become clear only later, often in tests, pilots, or even actual implementation. As such, it makes sense to discuss when, why, and how robot developers (should) make particular design decisions, and when, why, and how stakeholders are involved to provide input, co-develop technology, etc.

While the current engineering and product development methodologies prescribe early involvement of end-users, REELER's observation is that in several cases, the robot under development was shelved when it proved to be inadequate for users only after being implemented in practice. Section 6.1 provides an overview of potential causes for design inadequacy from the innovation, behavioral, and complexity economics perspective, notably with regard to the tendencies of individual robot developers to focus on technological aspects and rely on preconceptions of the ultimate application (which may be biased or partial). This is particularly so, arguably, when the development is fraught with technological and market uncertainty, e.g. in case of innovative service robots that need to execute relatively complex actions in socio-technical environments that are hard to predict and require tailored technology. In addition, underrepresented in empirical analyses are robot development projects that do not even make the pilot or implementation phases. Section 6.1 also provides a brief overview of potential causes for these technological failures.

Further complicating analysis of, and thereby providing recommendations on, the process of developing innovative technology is its distributed nature: the research and development are generally not conducted by individual developers, but may also include targeted end-users, and often a group of collaborating developers. Not uncommonly, these researchers and developers are employed by different firms and/or institutes. As such, the interactions of developers and hence (the change in) their understanding of robot technology and directions of technological development are (partially) restricted by the boundaries of the firms and institutes employing them and the nature of their relationships. Development and design activities may also take place at different points in time, hence only partially carrying over knowledge, often embodied in artifacts or codified without the tacit, situated context. Conversely, the robot developers also establish relationships based on their current understanding of the technology and market, personal preferences and history, language, local culture, etc. Moreover, the robot developers' perception of the design space available to them depends on the components available on the market and capabilities of suppliers. In addition, the market segment and users to target (and thereby the requirements to fulfill) are based on assessment of market and technological opportunities, which are also based on the resources available, capabilities, and commercial viability. As such, there is a complex co-evolution of the perception, technical specification, and materialization of user requirements and the innovation network of economic actors collaborating. As studies revealed that both form sources of technological lock-in and market unviability, innovation economics [1] as well as innovation management both stress the importance of balancing exploration and exploitation of collaborative relationships of economic actors in new product development. In fact, the last couple of decades, innovation management paradigms have evolved considerably, and currently notably emphasize exploration in terms of partners, openness in knowledge sharing, collaboration in knowledge creation, etc.

Indeed, the organization of robot research and development activities has evolved itself as well. In the 1960s, robots were developed mostly completely in-house by a few, mostly competing experimental entrepreneurs seeking to overcome basic technical challenges and targeting applications in rationalized manufacturing processes. By the late 2010s, the robotics industry had evolved to be composed of, on the one hand, established robotics firms supplying mature and modularized robots to manufacturing firms, and, on the other hand, swarms of newly entered entrepreneurs collaboratively researching & developing experimental robotic technologies. Section 6.2 provides an overview of innovation economics insights in the meso-level organization of robot development, notably how particular properties of technological and market knowledge require collaborative governance (in so-called innovation networks), face-to-face engagements, and co-location of development activities. In addition, innovation networks are embedded in innovation systems both facilitating and hampering technology development and market access. In part, when it comes to development of new products, the technological options are restricted and facilitated by the accumulated scientific and engineering know-how, both for the individual developers, the firm or institute at which they work, the (regional) pool of potential partners, as well as for the sector as a whole.

Moreover, the robots that developers seek to provide also change over time; entrepreneurs are developing new robot applications in sectors such as healthcare (e.g. surgical robots, exoskeletons), agriculture (e.g. precision farming, harvesting robots), education (e.g. robotic assistants), etc. REELER also established that there is a considerable role of funding organizations in directing research and developments in individual projects as well as the creation of pan-European knowledge hubs.

Apart from the short- and medium-term determinants of research, development, and design decisions, there are long-term determinants. Over the course of the last decades, the robot development challenges have evolved in a superposition of the traversal of the industry lifecycle (from inception to mature, at least for industrial robots), accumulation of technologies (e.g. refinement of sensors, increase of computing power, emergence of machine learning), growth and diversification of sectors of application (e.g. from the rationalized manufacturing process into agricultural, defense, space, healthcare, and education sectors), new product development methodologies (e.g. from a mostly engineering perspective to recognition of the fuzzy front-end), emergence of strategic management and innovation management paradigms (e.g. from R&D in vertically integrated firms to open innovation), and progressive insights in societal aspects and human factors to be taken into account (e.g. human-robot interaction), etc.

In fact, REELER is bidding robot researchers, developers, and builders to now also properly include a wider circle of stakeholders and to incorporate ethics in design considerations (beyond the usual safety, security, liability, ergonomics, etc.), notably early on in the development process.

Conclusively, this chapter analyzes the process of researching, developing, and building (new) robots subject to (i) the normative new product development methodology used to arrive at products in demand by end-users (regardless of industry lifecycle phase),[2] (ii) the behavioral, complexity, and innovation economic complications in product development such as fundamental uncertainty, bounded rationality, and technological modularization, (iii) the endogenous evolution of innovation networks involved in robotics both facilitating and constraining aforementioned activities, notably recognizing the institutional embeddedness, and (iv) the accumulation of technology within and shifting competitive focus over the course of industry evolution affecting the type of robots targeted and thereby the issues encountered during development.

1 Innovation economics is an emerging field seeking to uncover the economic drivers of innovation, the role of entrepreneurs and institutions therein, the (normatively 'best') organization of and environment for technology research & development, and policies to improve the innovativeness of regions, networks, and firms. Innovation economics studies the organization of development activities from the knowledge-based perspective, primarily concerning the collaboration governance forms, innovation network structure, geographical location of knowledge transfer and creation, etc. Innovation economics and innovation management both argue that certain governance forms, collaborative stances, and organizational structures of these interactions are conducive to the innovativeness and feasibility of technology being developed.

2 References to normativity in this chapter refers to best practices, not the normative 'blinders' discovered through the ethnographic studies.

6.1 New product development process

The past decades are littered with experimental robots that, once piloted in a real-world context, proved to be technologically inadequate, excluded particular users unintentionally, left users concerned about safety or privacy, etc. REELER's research contends that, at least in several of those cases, robot developers may have ignored the actual end-user too much or relied on intermediary spokespersons too much. Here, this contention is followed up with the analysis of robot developers' activities and decisions over the course of a (stylized) new product development process. Notably, while there are well-crafted methodologies to assist developers, these do not alleviate developers of having to cope with intricacies in complex technology development. This includes having to (i) decompose and distribute tasks (with various, possibly unintended consequences), (ii) fix either (hypothetical) user requirements or technical specifications at some point in time (under uncertainty about consequences thereof), (iii) iterate through development process stages upon encountering issues, and (iv) decide when to use accumulated technology, rely on standard methods and tools, etc. and when to develop something afresh. Given the pivotal role of market and technological uncertainty, the necessity to take design decisions regardless of that uncertainty, as well as the need to cope with limitations of understanding in doing so, several REELER researchers have conducted a fundamental experimental study of how human subjects actually cope with market and technological uncertainty as well as technological complexity in product development. Given constraints on the number of pages for this chapter, this section only highlights the main findings and insights on the robot development process.

6.1.1 An engineering and complexity economic perspective

In engineering (including software development and robotics), products are generally developed following design methodologies such as the waterfall model, Cooper's stage-gate model (Cooper 2007) and the NPD framework (Ulrich & Eppinger 2016). These 'product development processes' provide guidelines for activities, generally separated into discrete, consecutive stages (e.g. Cooper 1983), such as generating abstract ideas on the product to develop, preliminary assessment of market demand, formulating (preliminary) user requirements, conceptualization and specification of a functional design, constructing an artifact, conducting tests/ pilots/ trials, and then the product launch and implementation.

Contemporary updates of these development methods , such as 'agile' or SCRUM methodologies, acknowledge both the importance of involving users in various stages as well as pinpoint circumstances in which new iterations are required to reset user requirements, technical specifications, or system design. Moreover, we argue that the development process features, first, decomposition of the robotic system to be developed and subsequent recursive and piecemeal resolution of technical issues, second, multiple iterations over the various stages to act upon feedback, and, third, accumulation of technology that gradually locks in robot conceptualization and components used.

First, whenever, at the start of a development process, a robot is expected to become complex and require not only construction, but also development, and possible even research activities, robot developers may seek to distribute tasks over domain experts and over time. Such a distribution of tasks is, ideally, supplemented with a decomposition of the robotic system into modules and careful orchestration of technological choices across the various modules and across research, development, and design activities. In turn, the development of these modules is broken down into tasks of developing yet lower-level components, etc. Indeed, complex technology development is often piecemeal, recursive, and iterative. For example, think of how computer programs are gradually extended and in which frequent compilation and testing not only establishes a correct implementation but also helps the programmer to decide what to do next and how. Micro develop-test-plan cycles help developers to reduce the cognitive load. However, they also increase the need for relational responsibility (*see 4.0 Ethics Beyond Safety*). Note that robot developers already do partition activities into development of functionalities such as kinematics, motion, sensing, decision making, learning, etc. Moreover, both fundamental and applied research is conducted for most of these (Siciliano & Khatib 2016).

Second, the technological decomposition and distribution of tasks are subject to a specification of the functionality and requirements of a robot. Certain issues encountered at later stages, notably testing and actual implementation, force developers to return to earlier stages of the process and use end-consumer feedback in improving and updating the design. Arguably, at some point in time, robot developers and designers may start to involve end-users or representatives in the development-test-plan cycles (see also the notion of 'staggered expansion' introduced in section 6.2.2). Indeed, REELER's research revealed that the development of robots is definitely not a linear process from development in a laboratory to application. For instance, testing and pilot studies with early robot designs revealed that customers use the robot in unforeseen ways or in an alternative application environment. Indeed, not uncommonly, technological solutions proved to be subpar (i.e. below average) and forced robot developers to revise the user requirements, alter the design, etc., (*see examples in 4.0 Ethics Beyond Safety* and *5.0 Inclusive Design)* on how for instance robot developers need to adjust controllers so they fit smaller hand sizes. So, development failures and process inefficiencies may well stem from the fact that robot developers often develop and design robots with a biased preconception of the end-user in mind or, alternatively, have an intermediary representing the end-user, which introduces his/her bias (*see 5.0 Inclusive Design*).

That said, there are obvious arguments in favor of not involving users intensively at every stage. After all, this would be costly and the organization of pilots would be impractical. Moreover, while waiting for user feedback, robot developers cannot fix design specifications (often across the interface of robot modules), which effectively delays development activities and thus increases the time-to-market. In addition, more problematically, it is not always clear who is the ultimate end-user to be targeted, as this, in part, also depends on technological possibilities, and the fact that users may not have a concrete idea of how to use the robot in its underdeveloped form (see the **dilemma of specification sequentiality** discussed below).

Matters become even more complicated whenever robots operate in a human-centered service setting (e.g. a hospital, construction site) or become part of a larger socio-technical system (e.g. a farm, or a warehouse) in which the robotics community at large has little (reported) experience. In this case, it may be that the robot may be operated by non-professional users, the human decisions may interfere with the robot's heuristic, there may be changing input from external sensors and options for actuation, etc. (*see 4.0 Ethics Beyond Safety* for examples of how humans and robotic systems are sometimes incompatible). Such 'interactions' may well be so idiosyncratic that they are only uncovered in test trials, pilots, or even actual use after implementation.

Third, over various projects, developers, robotics firms & institutes, and the sector as a whole have accumulated physical artifacts, components, technological solutions, analytical tools, and even problem-solving routines. Moreover, particular dominant designs for the robotic system, communication protocols, and (de facto) standards (e.g. voltage, socket & plug types) have emerged. Arguably, a substantial part of the technology for robots (arm joints, actuators, sensors) is rather mature and is (preferably) acquired 'off the shelf' in new projects, particularly for industrial robots. Developers may (have to) alter or extend these standard components, solutions, and routines when encountering issues in implementation, facing new challenges, etc. So, in crafting new robots, developers may possibly go through multiple iterations of the product development process. It may be necessary to thereby recurse into (re)designing lower-level components, notably the components that prove to be problematic or hold back performance.

In the REELER cases, none of the entrepreneurial entrants into the emerging sectors (e.g. education, construction, agriculture, autonomous vehicles) engaged in radical innovation that challenged the entire robotics architecture. They rather sought to pick mature, standard modules when available. This allowed them to immediately focus on (i) modules that formed either the bottleneck in system performance (e.g. subpar image recognition and poor dexterity in case of a harvesting robot) or (ii) the pivotal technology in the unique, innovative service that the entrepreneur seeks to provide (e.g. personalized learning programs in an educational robot or detecting muscle contraction for actuation in a rehabilitation robot).

Obviously, the use case and application environment of 'downstream' customers (or end-users) reveal both regularities as well as idiosyncrasies that need to be addressed in the robot design. Particularly when physical aspects of components or embedded software have to be altered, the manufacturers 'upstream' have to be involved. As such, over the course of robot research, development, design, and implementation, there may well be interaction of the robot developers with downstream customers/ end-consumers and upstream suppliers of 'standardized' components. The involvement of the 'supply chain' parties in innovation is discussed in more detail in section 3.3.

6.1.2 A behavioral and innovation economic perspective

Particularly the last decade, entrepreneurs have started to develop robots for service sectors (e.g. cleaning, education, healthcare). In these sectors, robots may be operated by various and potentially multiple non-professional users, and notably in less controlled and variable environments. Moreover, robot technology targeted in these sectors typically is more complex than in the traditional manufacturing setting; robots may need to be able to execute many and less routinized activities, may need a high-level of dexterity to handle various objects, may need to process substantial amounts of sensory input data, etc. Moreover, the actual user requirements are not well articulated, the environmental conditions in which to operate are not completely known, the socio-technical environment is changing, some of the technology is still in an early state and evolving, etc. Developers thus, firstly, need to address the 'fuzzy front-end' (e.g., Reid & De Brentani 2004), and, secondly, need to cope with unforeseen opportunities, obstacles, and challenges.

First, for these new (types of) robots, development is not an engineering exercise of translating specific user requirements into a framework of readily compatible mature components picked off the shelf. Instead, robot development gets the character of both (co-evolutionary) market and technological research plagued by path dependencies due to the sequence of specifications as well as inherent uncertainty.

Particularly complicating matters is that (potential) users may have difficulties articulating what they want and how they would use a robot, notably because the robot is yet ill-specified. Moreover, robot developers may have difficulties specifying realistic and sufficiently concrete technical capabilities of a robot without

Dilemma of specification sequentiality (and bootstrapping out): *Fundamental dilemma in new product development that requires a developer to either fix technological specifications to determine detailed user requirements or assume user requirements to determine basic specifications for technology to develop. Both decisions limit future options. The solution proposed here is to 'bootstrap' out by alternating between obtaining user feedback with increasingly more specific designs and trying to materialize new product technology based on increasingly more concrete user requirements.*

knowing how and where the robot is to be used. As outlined above, a typical engineering approach is to *assume* particular user requirements and characteristics of the environment of application, develop the robot to an experimental product, and then engage in adaptation and finetuning after running pilots with the robot in (staged) real-world setting. However, in REELER case studies, such *'forced early neglect'* of users has led to mothballing robots several times (*see Nickelsen, 2018 and Story from the field: Multidimensional inclusion challenges in 5.0 Inclusive Design*). Conversely, selecting particular people as potential users, and taking these potential users' initial ideas for research and development is also risky. After all, technological research activities may stray away from existing technological expertise so leading to (unnecessarily) costly developments (so, focused on 'wrong' targets), may cause squandering resources on research for various market segments ultimately not targeted (so, not focused enough), or ending up with feasible technology but for an ultimately commercially unattractive niche (so, too focused). So, robot developers face - what we coin as - the *'dilemma of specification sequentiality'* and have to choose between two undesired situations. Arguably, a viable way out of this predicament is to gradually 'bootstrap' by alternating between obtaining user feedback with increasingly more specific designs and trying to materialize new product technology based on increasingly more concrete user requirements. So, as such, one would expect a temporal interleaving of market and technology research with a gradual convergence toward a product materialization and specific market segment to target. Note that the various new product development frameworks do stress this iterative character of the process. What is added here, though, is that robot developers may possibly consider running multiple exploratory research projects, thereby postponing irreversible investments that are costly or have an otherwise significant impact on options later. A more detailed treatise is considered out of scope, however a possibility is also to include alignment experts (*see 13.0 Conclusion*).

Uncertainty: *Property of technology and market research as well as product development & design activities that economic actors need to cope with.*

Further complicating matters is the acknowledgment, that research, and development of new technological knowledge is complex, fraught with uncertainty, and does not allow rational optimization. Economic actors not only have to cope with an ill-defined technological target, but also with a partial view of the technologies available, a possibly incorrect understanding of operational principles, partial knowledge of effects of certain changes, etc. In fact, whenever the developers make decisions based on such imperfect information, the consequences of research, development, and design decisions may become clear only later. This also reveals the existence of uncertainties in actors' decisions and reveals deficiencies in the competences of the involved actors. So, the research for and development of new technology is characterized by uncertainties in the viability of market decisions (e.g. *who* are my customers? Are they the same as end-users? *What* do customers want? *How many* customers want this?) as well as uncertainties in technological feasibility (e.g. Can I make X? Does X work for Y? If I change X, would Y still work?). Notably in case of a *breakthrough innovation*, which requires a combination of technological knowledge from, generally, disparate fields, there is -by definition- no a priori quantifiable assessment of whether particular search directions lead to feasible technology or not. In this case, developers need to cope with *fundamental (Knightian) uncertainty* (Knight 1921) (nota bene: unknown unknowns). In developing new technology, developers have to look for a fruitful mix of a wide variety of concepts and technologies from a range of (possibly) related fields. The number of combinations generally is tremendous, and it is practically not possible to investigate all of them. This is further exacerbated by the fact that, for a basic assessment of technological feasibility, an elementary understanding is needed, possibly requiring some basic knowledge transfer, absorption, and imaginary application. As such, developers must overcome *combinatorial complexity*, e.g. by following conjectures on operational principles, design analogies, etc.

Bounded rationality: *Human cognitive limitation in rationalization of decisions.*

A more general notion, found in behavioral economics, is that humans are boundedly rational (Simon 1982), generally lack perfect foresight, and suffer cognitive limitations (e.g. manage to keep at most 7 +/- 2 chunks in memory (Miller 1956)), due to which humans use rules-of-thumb and effort-reduction mechanisms in their decisions (Tversky & Kahneman 1974, Shah & Oppenheimer 2008). In case of technology search, the uncertainty and complexity forces humans researching, developing, and designing new products to rely on (generally) non-optimal, heuristic search strategies. Humans may do so, for instance, by postulating and testing novel operational principles and using them to construct new technological paradigms, develop a range of new product design, trying a near-exhaustive range of new materials (such a 'dragnet' approach was followed by Thomas Edison quite frequently), etc. Clearly, such an approach is experimental, and, as a consequence, pilot studies and tests with targeted users in real-world settings are likely to show that the technology being developed does not meet all user requirements or violates some environmental constraints.

Interestingly, although behavioral and innovation economic researchers have pinpointed such human shortcomings in technology search, there has yet been done little experimental research in actual, operational behavior. REELER researchers with a base in economic disciplines have conducted several behavioral experiments to gain insight into this presented below.

STORY FROM THE FIELD:

Product Design Game – experiment on coping with uncertainty and complexity

REELER conducted an experimental economics study to analyze how humans cope with technological and market uncertainty as well as technological complexity in trying to construct market viable and technologically feasible products given a certain resource scarcity. To this end, a web-based 'product design game' was developed in which subjects have to, individually, try to solve a series of product design challenges. The goal was to build a *working* product constructed by connecting various modules and thereby ultimately providing modules that are *in demand* by as many end-consumers as possible. However, the subject has only a limited number of coins and has to decide *when* to spend these resources and whether to spend these on (a) obtaining information on what modules a randomly drawn consumer wants, or (b) obtaining a (randomly/ selectively) drawing a module from an invisible set. Complicating matters for subjects is that there are only a few combinations of modules feasible and there are only marginal visual cues on whether a combination is feasible or not. Moreover, subjects can (but need not) select a module it owns and focus technological research on finding a module which makes a suitable combination. That said, even if modules form a feasible combination (the product is technically feasible), there need not be demand for it (the product may not be market viable). This 'product design game' thus has human subjects cope with technological uncertainty (e.g. 'I do need this input module, but does it exist?'), technological complexity (e.g. 'can I construct a feasible combination out of this set of modules?'), market uncertainty (e.g. 'what do consumers want?', 'is there demand for the product I have constructed?'), and scarcity.

Distributed over four sessions (three in 2018 and one in 2019), a total of nearly 200 subjects took on a series of 'product design challenges'. After arriving at the university and taking a seat in the lecture hall, subjects received initial instructions on the purpose of the game and elements of the graphical user interface. Subjects were then asked to individually try to complete 16 product design challenges, presented to them in random order. For each challenge ('round'), all mouse moves, actions, obtained market information, discovered modules, created products, feasibility and market viability was recorded and statistically analyzed. Of particular interest now was whether human subjects become better over the course of multiple challenges (i.e. do they gain proficiency in designing?) and what research patterns for design challenges emerges for successful that become successful (i.e. is there a universally superior design roadmap/ new product development process?).

The results for the first six challenges were regarded as the ramp up phase in which subjects have to get to know the graphical user interface, have to get an understanding of what the challenge entails, while the last ten challenges were considered to represent the actual learning of the design strategy. While the experiments showed that subjects indeed start to apply increasingly stable strategies, these strategies differ from the conjectured New Product Development roadmap and, moreover, there were substantial differences between cohorts of subjects. Although plagued by uncertainty, a small percentage of subjects developed a (stationary) heuristic roadmap for product research and development activities which almost always led to a market viable and technically feasible product. Given the resource scarcity, it was not only an effective heuristic, but also allowed the subjects to cope with the combinatorial complexity in conjunction. That said, most subjects fell back to boundedly rational, fast-and-frugal heuristics with relatively poor performance. Apart from displaying visual layout techniques to reduce cognitive load, subjects also had tendencies to overlook market research and overly focus on technological research, sometimes even having a blind spot for particular technological research options. An illustration of the application of boundedly rational strategies is found in Figure 6.1. It contains a photograph of the screen of one of the subjects after almost 75 minutes, so of one of the last challenges.

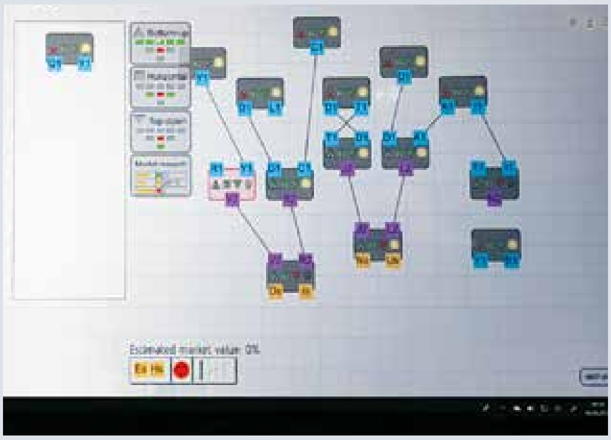


Figure 6.1. Photograph of a screen of one of the subjects, actually of one of the last challenges. (Photo by Ben Vermeulen)

A closer look at the screen reveals that the subject has already constructed a completely feasible product (on the right half of the screen) and has almost finished a second product, which is also almost feasible. In fact, the mouse pointer is hovering over a particular technological research button (for bottom-up focused search). This choice is indeed part of the most successful strategy, so the subject understands the 'engineering' part of the challenge very well. However, the subject is trying to find an input for the selected module (in light red) and is thus trying to construct a feasible product. However, the market information in the table at the bottom of the screen does not show any demand for the features of that product. As such, the market information is effectively ignored.

On another occasions, another subject was seen to conduct focused technological research (so, again, this rather involved concept was well understood) and managed to construct a completely feasible product. Only then the subject pressed the market research button *for the first time* and sighed and raised its hands into the air in disappointment that there was no market demand for the product! After the session, the subject was asked why (s) he did not conduct market research first before investing so much in technological research. After a short pause, the subject noddingly acknowledged the mistake.

Stressing that the usual caveats apply, the findings from the experiment indeed indicate that humans suffer from cognitive limitations and bounded rationality. There was however a substantial and persistent difference in performance.[3] Translating the findings to the context of real-world product development, developers may be overly focused on developing a top-notch product for the mainstream market segment, thus disregarding indications that this may be technically unattainable. That said, more likely may be that developers are overly focused on developing a feasible product (taking it on as a personal challenge), thereby missing indications that market demand may be absent or insufficient to recoup development costs. In any case, not surprisingly, haphazard or simplistic heuristics in development are likely to be inefficient and prone to failure, which actually underlines that research and development activities require a contextual rationale (e.g. user requirements or technical reasons) (*see 7.0 Learning in Practice*). That said, technological research and development may be too unfocused, effectively overburdening developers. More focused and depth-first developments may increase chances of finding both market viable and technically feasible products (and again these could include alignment experts, (*see 12.0 Human Proximity and 13.0 Conclusion*). There are several more concrete product development recommendations, but these are arguably outside the scope of this publication chapter.

6.1.3 Ethnographic findings and methodological ramifications

The main deliverable of the REELER project is a Roadmap to guide collaborative learning and relational responsibility between robot researchers, developers, and users (and other stakeholders). To this end, extensive ethnographic studies have been conducted to uncover robot designers' assumptions and practices in discovery and incorporation of actual needs of stakeholders in relevant situations. As such, these ethnographic studies could reveal 'best practices', but also biases, shortcomings, and pitfalls. The research findings are reported and used throughout this publication. Benchmarking could then possibly reveal how to ameliorate product development and design practices, notably suggest how to time and tune collaborative learning between robot developers and (different ranges of) stakeholders (e.g. by introducing means to signal and anticipate an emerging lack of human-robot proximity, mitigate or deal with ethical issues).

In the many interviews conducted, there were questions included on the new product development and design process. However, the answers were not giving coherent insights into design processes and provided limited insights on the actual timing for design decisions, what was the status quo of market information at the time, what ultimately led to the design decision made, etc. Indications of these can be found in some of the more comprehensive field studies (e.g. Nickelsen 2018, Sorenson 2018, Hansen 2018). However, in general, not even detailed field studies can cover all the non-linear decisions in design processes. For instance, people have difficulty recollecting actual sources of information and orderly reporting complex interactions. Moreover, they tend to introduce biases in their recollections by selective abstraction, overgeneralization, magnification, etc.

That said, the interviews provided valuable support for claims made in the previous sections. Moreover, analysis across the heterogeneous cases revealed three additional complications in the (organization of the) development process.

First, development decisions are often taken in a distributed and decentralized fashion, e.g. in part in previous research projects, in part embodied in artifacts passed down, sometimes stored in shelved knowledge codified by actors not or no longer involved and hence devoid of (tacit) context. As such, interviewees indeed were only able to reveal parts (in terms of time, innovation activities, social network, and technology) of the design process, and a subjective interpretation at that. Consequently, the actual design space for individual

3 Triangulation with a questionnaire applied prior to the experiment revealed that this difference may be attributable to the computer game savviness of subjects, in part. While results may thus be biased due to instrumentation, it does in fact imply that real-world product developers with a particular aptitude for analytical instruments, problem solving techniques, and the tools used in design, may well be more successful.

developers was often limited, due to which decisions occasionally were suboptimal from a system perspective. In addition, the actual research, development, and design process in practice has been found to be messy, highly iterative and recursive (at least at the engineering level), and at times highly interactive (and occasionally with a prominent role for informal contacts or unusual sources), further complicating attempts to coordinate design decisions.

Second, robot developers frequently encountered complications in fixing user requirements that go beyond mere market uncertainty (or specification sequentiality). The ethnographic material revealed cases in which robot developers faced *trade-offs* (Consumer X does like A and B, but the design can technically not offer both at the same time), *conflicts* (Consumer X likes A, Consumer Y dislikes A), and *in-/exclusion* decisions (Consumer X likes A, Consumer Y likes B, but the design cannot offer both at the same time), occasionally even only during trials or after implementation. Expounding design solutions in an explicit social context helps designers to uncover the existence of such trade-offs, conflicts, and exclusions. Subsequent design decisions are then, ideally, made with an explicit contextual rationale, and particularly those that are time- or resource-consuming or costly to reverse.

Technology transfer: *The process of adapting technology to particular usage or in an environment different from when originally conceived.*

Third, as argued before, robot developers necessarily have (more or less) specific user requirements and application environments in mind when researching, developing, and designing their robot. This may lead to complications when the robot is later implemented in a different context not considered earlier. This may concern, for instance, different types of users (e.g. gender, age, handedness), different operational context (e.g. outside instead of indoors), etc. Moreover, as design is always situated, robots inevitably embody cultural elements. This may lead to complications not uncommonly due to rather elementary issues such as the use of particular symbols (e.g. on buttons), language (e.g. speech recognition), appearance (e.g. toy-like), manner of addressing users (e.g. too (in)formal), etc. An illustration is provided in the Story from the field about the South-Korean robot Silbot, found below. While "designing for transferability" may be considered a far-fetched recommendation, some complications may be anticipated by up-scoping the usage considered (albeit risking a lack of focus) (*see also 5.0 Inclusive Design*).

The Silbot story demonstrates how diverse cultural values challenge processes of technology transfer (Photo by Lasse Blond; See Story from the Field, page 119)

STORY FROM THE FIELD:
The Case of Silbot

In the fall of 2011 and the winter of 2012 experiments took place in elderly care centers in Denmark and Finland where a South Korean robot named *Silbot* was tested. Silbot is developed by a tele-education robot by the name of *EngKey*, invented by the *Korean Institute of Technology* (KIST). The original intention with the robot was to assist English teaching in elementary schools in South Korea where the robot was built to function as a *wizard-of-OZ* English teacher. Wizard-of-OZ refers, here, to the technique by which a robot is operated by a remote teacher outside of the classroom. This function of the robot was tested at 29 schools in the republic between 2010 and 2011 (Guevarra 2015).

Later, Silbot was reprogrammed to facilitate 'brain training' exercises for elderly citizens suffering age-related illnesses such as dementia in a project named *Brain Fitness Class with Elder Care Robots.* The robot was at first tested at the Gangnam-gu Center for Dementia in Seoul and then went overseas to be tested in Denmark and Finland with a mixed and explicitly cultural reception. In Finland, the robot was soon discarded, whereas in Denmark the staff at a local rehabilitation center worked at lenght to make it culturally accessible (Blond 2019). Silbot (and an accompanying robot named Mero) were supposed to oversee 16 cognitive digital games such as *Bingo, Puzzle*, a calculation game, as well as an exercise where participants were supposed to remember a route taken by Silbot on a checkered floor and walk it. The following is an excerpt from an article explaining some of the challenges the Danish staff faced with the technology transfer. At first the citizens were rather unimpressed by the robot, but eventually they began to engage with it.

"There were actually several who said they thought SILBOT was not important. Then I confronted them and asked them: 'Well, you said SILBOT was unimportant. So why did you then walk over and said 'have a nice weekend' to it?'" (Line, nursing home staff) (Hasse 2015a).

Staff and citizens treat Silbot as they would each other - greeting it politely. Before it came to this cordial relationship Silbot had to be reconfigured in order to take part in the amalgamations formed at the rehabilitation center. The problem was that the robots' brain training program developed in South Korea was directly translated into Danish. This translation turned out not to fit the cultural context of the Danish rehabilitation center and its citizens. In the direct translation the 'teacher' seemed to speak clear Danish, but when the robot was put to use at the nursing home, Silbot was perceived to be rude, and in need of a lesson in politness. It scolded users for not getting the answers right in their brain training exercises. Robots as artefacts are not carriers of culture. It was in the meeting with the local cultural ecology that the healthcare staff's expectations of how a robot teacher should, or should not, address citizens emerged. Here Silbot was conceived as very rude and demeaning that had to be stabilized through re-programming.

"It's been reprogrammed after it has come to Denmark. It is not as angry, hard and cold anymore as when it came. In Korea you have a winner and a loser. So, it's a completely different culture. It has been programmed in a different way because it simply scolded the participants when they answered incorrectly. It had a completely different cultural approach to learning than we use in Denmark," Erica explains (nursing home staff) (Hasse 2015a).

In his thorough study of the diverse cultural receptions of Silbot in Denmark and Finland, Lasse Blond concludes that: "The recipient culture is constantly changing and at stake in the adaptation of Silbot." (Blond 2019, 211)

6.2 Meso-level organization of development

In Schumpeterian perspective (Schumpeter 1942), in a capitalist economy with unfettered competition, the capability to innovate is of vital importance to any firm. As such, in the long run, the primary source of the competitive advantage of a firm is its current stock of technological knowledge, its capability to acquire and create novel knowledge, and its ability to commercially exploit that knowledge in innovation (Kogut & Zander 1992). Given the technological developments by head-on rivals or research institutes in the same, related, or yet unrelated sectors, firms have to monitor, screen, filter, acquire, and put to use technological knowledge from outside the firm into new products or services. This also holds for the robotics sector and regardless of whether that focal firm is an established robotics firm active in building robots for the mature sectors (e.g. manufacturing, warehouse logistics) or rather a small entrepreneurial firm getting started with research and development of experimental robots for new sectors (e.g. agriculture, healthcare). After all, the focal firm may either need to preempt or at least timely follow rivals innovating their robots, or to create and enter a (new) market with a new type of robot. Moreover, also the sectors of customers are evolving subject to process innovation, such that the requirements and specifications may well change. Here, it is discussed how firms access and acquire new knowledge, how characteristics of such knowledge affect the mode of governance (buy, make, or collaborate), how this thus spans an innovation network, and how such an innovation network evolves over time.

6.2.1 External sources of technological knowledge

Over the course of researching, developing, designing, and adapting an entire robot, or systems or components used therein, robot developers may seek access to robot technology and underlying knowledge produced by other robot developers, possibly residing at another firm or institute. Generally, however, most of such (new) technological knowledge is not a 'public good' that is freely accessible and easily acquired to (competing) developers. Instead, access to new technological knowledge is often limited, possibly deliberately restricted (which is possible if knowledge is a 'private good'), and, in fact, robot developers may even be unaware of the very existence of particular technological knowledge. Moreover, access to and the ease of knowledge transfer depends on the capabilities of the actors involved. Given the scope, this publication gives just a brief overview of the most common issues in accessing, transferring, absorbing, using, and developing new technological knowledge.

First, even if a robot developer is aware of and has (unrestricted) access to technological knowledge related to the developments undertaken, the developer may have a limited **absorptive capacity** (Cohen & Levinthal 1990), i.e. a limited ability to immediately understand and use external technological knowledge. In part, absorptive capacity relates to fit of the field of expertise and the associated mental (ontological) framework of an individual developer and the elements of the technological knowledge sought to acquire. There are several ways to increase the absorptive capacity, e.g. conducting research in adjacent technological fields to expand the ontological framework, collaboration with those that do comprehend the focal technology and can thus explain relationship with concepts that are already understood, etc. Note that the concept of absorptive capacity is used at different levels of aggregation, e.g. the collective of employees jointly also span the absorptive capacity of a firm.

> **Absorptive capacity:** *A concept expressing the (often limited) ability of people (e.g. engineers) to comprehend and use external, new technological knowledge entirely.*

Second, in case of (radically) new technology, much of the technological knowledge is tacit (i.e. implicit, unexpressed) rather than codified (i.e. stored and easily transmittable, e.g. in documents), and the operational principles and internal mechanisms of the technology are understood almost exclusively by the primary developers. This complicates transmission and acquisition of technological knowledge. Direct, verbal, and preferably face-to-face communication is crucial, particularly when the new 'alien' knowledge sought to acquire and absorb is still largely tacit (Nonaka 1994). This is the case, for example, in the early stage of development of breakthrough technology; source and receiver of knowledge may have a substantially different understanding of the operational principles used, the receiver may have crucial omissions in its ontological framework of the technology, etc. Importantly, due to the tacit nature of knowledge as well as the efficiency of absorption of knowledge, there are substantial advantages of co-location of research & development activities in technology clusters/ regions.[4]

> **Co-location / face-to-face communication of tacit knowledge:** *Observation that tacit knowledge is best communicated in face-to-face communication. Actors engaged in processes requiring frequent exchange of such knowledge best co-locate for efficiency.*

A REELER case study on a harvest robot (SANDY) revealed that a further refinement is to be made. In this case, a particular early-stage design from a previous project was adopted. Like argued before, robot developers sought to improve particular crucial components (a specific sensor-actuator combination) which also required frequent field tests. In this case, the actor engaged in development of that sensor-actuator combination and the firm at which the pilots were run were in close geographical proximity. As, however, the robot design was already modularized, the work on other modules took place by partners further away and meetings with them

4 Note that there is a variety of other advantages as well such as a shared pool of skilled workers, attraction and development of specialized suppliers, sharing of knowledge platforms such as universities, etc. The interested reader is referred to literature on the so-called Marshall-Arrow-Romer externalities.

were infrequent (see discussion of the distributed character of technology in *4.0 Ethics Beyond Safety*). So, whenever the product design has been modularized, firms may work on separate modules relatively independently and geographically apart. Whenever the performance of technology is inhibited by the architecture itself or by poor interaction of modules, intensive collaboration and thereby geographical proximity is commendable.

Third, particularly challenging in the acquisition of technological knowledge is that there is, in general, a market failure: the actual price of knowledge can only be determined when the acquiring actor actually knows and understands it, but that effectively takes away the necessity to engage in the transaction in the first place.[5] As such, firms cannot acquire the knowledge on the market. Moreover, developing knowledge fully in-house is not particularly efficient, if possible at all, and replication is not efficient from an industry-perspective either. More importantly, once valuable knowledge has developed, the knowledge can be leveraged as a bargain chip in absorbing and accessing knowledge of others. As such, collaborative knowledge development seems the preferred governance form (Grant & Baden-Fuller 2004), which may take the form of supplier-buyer partnerships, outsourcing agreements, joint research projects, cross-selling arrangements, franchising, etc. Moreover, as firms have their own fields of expertise and would like to 'shop around' what other firms have to offer now or in the future, firms are generally hesitant to vertically integrate into corporate activities upstream or downstream. The need to shop around is also closely related to the technological and market uncertainty discussed before. Indeed, in many cases, firms would and should prefer a collaborative governance form, both in exploring potential fruitful knowledge exchange as well as in actual co-creation of innovative technological knowledge. That said, it does happen occasionally that established firms acquire specialized entrepreneurial firms to incorporate research capabilities and innovative knowledge. Similarly, it does also happen that established firms create spin offs of specialized activities that may be more likely to flourish when ran as independent firm (see e.g. the Story from the Field telling the story of the robot EULA, section 4.3.1). Note that while knowledge sources external to the firm are valuable in new product development, they are mostly used for access, idea generation and cross-fertilization. Firms' own internal production and technological knowledge is required for further problem solving (*see Kuwashima 2012* for a historical overview) and the development and production of the new product.

Collaborative governance form: *Given the market failure for and the uncertain, temporary value of knowledge, firms prefer collaboration in exchange and creation over market transactions ('buy') and vertical integration ('make').*

5 Arrow's information paradox, see Arrow (1974) and Grant (1996).

Last, knowledge developed by one actor may *spill-over* at no or relatively low costs to other actors. The latter actors thus *free-ride* on the investments of the earlier. Such spill-over free-riding is a disincentive to conduct research and development and a classical argument in favor of R&D subsidies. In this view, basic research has to be financed by the government, e.g. by grants to public universities and research institutes.

Free-rider problem: *Whenever everyone can use new knowledge for free, nobody is willing to invest in research and development, such that, consequently, the amount invested in research and development is (too) low.*

While particular types of inventions may be feasibly kept secret (e.g. a production method, software that can be obfuscated, a chemical formula), other inventions can be reverse engineered easily. Particularly for the latter, commercial firms (may) seek alternative measures to appropriate value of their intellectual property,[6] e.g. by means of patents, trademarks, marketing, rapid upscaling, or relentless innovation. Most important are patents, which from an economics point of view, guarantee a temporary knowledge monopoly and also disclose the knowledge in the freely accessible patent document.

Means for value appropriation: *Ways for actors to ensure capturing the monetary rewards for conducting research and development of technology, e.g. patents, secrecy, branding.*

6.2.2 Innovation networks

As already outlined, innovation economists argue that firms are engaged in an ongoing technological competition (generally alternating between product and process innovation over consecutive lifecycles, *see section 3.4.1*), which makes the ability to absorb, access, and create new knowledge paramount to their survival. Until the mid-1980s, the dominant paradigm for firms' strategic management was based on cost and price competition. Firms generally behaved as adversaries and were engaged in head-on competition. New product development was conducted mostly *internal* to the firms. In the 1980s, the resource- and competence-based perspectives emerged (Barney 1991), which stressed that a firm's sustained existence derives from having unique, hard-to-imitate, durable capabilities *making it an attractive, competitive supplier.* Indeed, firms should be striving to remain a favorable supplier by innovating. To this end, firms should specialize on and leverage the core competences, whereby a certain degree of vertical specialization is both efficient, reducing risk, and allows 'shopping around' for complementary knowledge. This gave rise to vertically specialized firms connected in supply *networks*. Moreover, to a certain extent, the firms in these

6 This leads to both a temporary monopoly and an efficiency problem which cannot be solved simultaneously.

networks have a common interest: providing a commercially interesting product or service to the final customers or end-consumer.

With progressive vertical specialization, though, the organization of research and development activities becomes challenging. The previous section highlighted several impediments to accessing, acquisition, diffusion, and creation of technological knowledge purely due to the characteristics of the underlying knowledge and humans as its vehicle. Particularly acquisition of new knowledge (and hence diffusion) does not occur spontaneously, but firms need to create channels for knowledge exchanges with other economic actors, generally based on direct compensation but more often based on a certain level of reciprocity. Ultimately, these R&D collaborations span innovation networks. (*See e.g. Hagedoorn 2002* on the rise of collaboration in research and development.)

Such innovation networks may well be different from the supply networks used for the manufacturing of existing products or provision of existing services. Whenever firms engage in new product development projects, they may indeed involve current suppliers or customers because of their specialized knowledge (and innovation capabilities) or to ensure future compatibility and/or manufacturability. However, in new research and development projects, firms may also break away from existing relationships (Rosenkopf & Padula 2008) and involve new partners, not only new firms, but also research institutes, cooperatives, etc. So, the innovation networks may well be more heterogeneous than production networks, may contain actors with competences far from production, and may have a structure quite different from the technological decomposition of the product. In publicly funded research, this is not uncommonly the case. Moreover, such innovation networks may be rather fluid and feature relationships that are severed whenever exploration does yield not leads for further collaboration, relationships that are dissolved after exchanging and cross-fertilizing knowledge, and relationships that even turn into durable buyer-supplier ties in the emerging production networks. Notably, for an outside firm or research institute to get invited into an innovation network (either formally or, at first, informally), there have to be prior indications that the actor in question may be the provider of complementary, potentially innovative knowledge. Moreover, given the 'erosion' of the innovative value of knowledge once it has been used or competitors have presented something superior, actors are particularly considered valuable if they show to have the capability to create new knowledge that is again of value to partners in the future. Indeed, firms need to acquire and update capabilities to explore and isolate relevant knowledge outside the firm, then acquire and absorb that knowledge, and subsequently use that knowledge to alter current products and production processes (Verona & Ravasi 2003). In general, in many industries, firms are involved in dynamic, evolving innovation networks with collaboration across the globe (Liu, Chaminade, & Asheim 2013). Arguably, from this perspective, an indispensable capability for firms is to initiate or get into a relevant innovation network, manage local relationships therein, and timely extract and organize valuable product propositions. Do note, however, that also the structural properties and the location of particular actors in an innovation network determine access to particular (types of) knowledge and thus decisively shape the creative aspects of knowledge diffusion and creation (e.g. Vermeulen & Pyka 2017).

REELER ethnographic research revealed that the population of actors engaged in robot development is diverse and ranges from large, established firms that build industrial robots with modularized technology for mature industries, to specialized component developers researching and developing components like grippers, sensors, and software, to institutes doing fundamental research on modules or rather applied research on experimental service robots, to small, entrepreneurial firms that seek to leverage particular technical capabilities to create new niches in healthcare, education, etc. As discussed in section 6.1.2, the robotics sector may be segmented by (the sector of) application. On the one hand, there are mostly large, established firms developing and building robots for use in manufacturing, automotive, warehouse logistics, etc. On the other hand, there are niches of (often) small, entrepreneurial firms (including start-ups and university spinoffs as well as business units of large established firms) engaged in research, development, and building (experimental) robots for application in agriculture, healthcare, education, construction, space, etc. Particularly for the latter 'niche creating' robotics firms and institutes, public funding is a major driver, notably because there are only few commercially viable applications, there are many technical challenges and demanding circumstances to resolve. Arguably, some of the robotics innovation networks studied are fairly typical for the early research stage of the robots being developed, i.e. requiring a substantial amount of analytical work. Much of the robot research and development took place in heterogeneous research projects with specialized actors with or without actual customers (e.g. SANDY, REGAIN), two-tiered business-to-business networks in which robot technology is either passed down after research at large research institutes or acquired on the market (e.g. WIPER, COBOT). Moreover, in some networks, there is a prominent role for universities (e.g. REGAIN, SANDY), knowledge institutes, and industry platforms (*see for examples 2.0 Robot Beginnings* and *3.0 Collaboration in the Inner Circle at www.responsiblerobotics.eu*). Some of the firms are small entrepreneurs seeking intensive collaboration with potential downstream customers and some firms are deliberately spun off of existing industrial robotics companies (e.g. COBOT, *see 4.0 Ethics Beyond Safety, section 4.3.1, the Story from the Field about the EULA robot*).

As mentioned in 4.0 Ethics Beyond Safety, EULA is the result of a technology first developed at the State Aerospace Centre (AC), then moved to the research department at the COBOT company which developed it to its present TRL9. Today, the robot is in mass production at the COBOT factory. The parts for the robot are delivered by different companies and subcontractors. For instance, the transmission equipment is from *Smooth Drive*, the motors come from *PS Systems*, and the sensors from *ReadyDrive*. Both *PS Systems* and *ReadyDrive* are spin-offs from the State Aerospace Centre. The rolling bearings come from a Dutch company (*The Dutch Ball Bearing Company*) and a French company (*TXT*), and some of the other big bearing's companies.

In fact, the actors engaged in analytical/ science-based innovation activities (such as studying key parameters for interaction between physical parts, e.g. SANDY) are located in relatively close proximity, while the actors engaged in synthetic, engineering-based innovation and recombination of rather standardized components (may) collaborate at greater distance [7] (*see section 6.3.2 on the spatio-temporal patterns in collaboration*).

Staggered expansion: *Strategy to expand the group and type of stakeholders involved in specifying user requirements, and test/ pilot runs over the course of several new product development iterations. For example, first focus on stylized requirements defined in-house, then involve intermediaries, then involve lead-users, etc.*

Some of the REELER case studies revealed an interesting particularity, namely that during the development of types of robots, so-called intermediaries are involved as 'spokespersons', rather than the actual end-users of robots. In some cases this is problematic if managers speak on behalf of workers without knowing about their actual work life (*see 10.0 Meaningful Work*). However some cases involve both end-user as the final beneficiaries and for instance staff or physiotherapists as directly affected stakeholders (e.g. SPECTRUS and REGAIN), who become were involved in the early developments in order to explain what is needed on their side to make a robot work (thus in the end benefitting the patients). In case of the educational robot (ATOM), teachers were also to some extent involved together with the pupils. Arguably, over the various iterations of research & development, it is likely that both requirements and technical specifications become increasingly more concrete and fine-tuned to end-consumers. So, over the development process, it is well imaginable that robot developers first engage in development operating purely on the basis of assumptions about the user, then involve intermediaries (possibly in several iterations), and in the later stages start to fine-tune with the final users (possibly in several iterations). A word of warning of this '*staggered expansion*' strategy for obtaining user requirements, information on the environment of application, etc.: blind spots, biases, ignorance in the developers' assumptions on and the intermediaries' perception of these requirements may cause severe shortcomings in the actual use that are costly to resolve and had better been anticipated by earlier involvement of end-users in develop-test-plan cycles. Of course, the aforementioned 'dilemma of specification sequentiality' still holds: intermediaries and users ultimately need to see and use some test version or materialization of the robot to be able to refine and articulate the requirements.

6.3 Evolution of technology and society

As we have seen in the previous sections, robot developers are engaged in short- and medium-term processes of concrete robots development at the micro-level and exploration & exploitation of the network of innovation partners at the meso-level. On top of these short- and medium-term and partially firm-specific agendas for robot developers, the robotics sector goes through consecutive, medium- to long-term lifecycles each consisting of several phases. Due to the bouts of innovation activities particularly in the early phases of the industry lifecycles, there is a long-term, bursty accumulation of technology and scientific and engineering knowledge, which is created, altered, extended, and possibly dismissed over time and possibly across lifecycles. While technology progresses, firms in co-located (possibly technological specialized) clusters may either drive, follow, or fall behind on technological development. As such, there are long-term geographical shifts of sectoral activities. Moreover, at the same time, society is evolving, in part responding or anticipating the introduction of the focal technology, which reflects in concerns, market targets, institutional arrangements, etc. for developers to take into account. This section is devoted to these three long-term processes.

6.3.1 Industry lifecycle and spatio-temporal patterns in collaborative innovation

Over the course of time, most technologies are often incrementally improved or adapted to local use or culture. However, occasionally, a radical innovation brings about a substantial increase of performance in some key parameter(s), which causes a boom in product innovation activities to apply the focal technology in new areas, effectively starting a new technology lifecycle. According to the various industry/ product lifecycle theories,[8] the intensity and type of research & development of firms is contingent on the extent to which these firms have readily explored and exploited technological and market opportunities. In fact, there is an 'inception phase' of technology development during which there are many competing, innovative, and experimental technologies with large parts of the knowledge yet uncodified. Firms are primarily engaged in exploration. As such, they are likely to postpone irreversible investments to acquire *specific* technological knowledge and build *particular* technological capabilities. Due to an interlocking of gradual articulation of market preferences, the shake-out of product designs and technological ideas, crossing a tipping point in market uptake, favorable economies for production upscaling, etc., a so-called de facto *dominant design* emerges. In the subsequent 'mature phase', firms

7 Here, the distinction between analytical/ science-based knowledge (e.g. life sciences), synthetic/ engineering-based knowledge (e.g. food processing, automotive components, mechanical engineering) or symbolic knowledge (e.g. moving media) is used. See Asheim & Coenen 2005, Asheim & Gertler 2005, Amin & Cohendet 1999 Martin & Moodysson 2011.

8 The industry/ product lifecycle literature has its roots in seminal papers from the 1970s and 1980s; Utterback & Abernathy 1975, Anderson & Tushman 1990, Hannan & Freeman 1977.

targeting the main segment of the market adopt the dominant design. As of that moment, competition no longer revolves around product innovation anymore, but rather around price, market share, etc., inviting rationalization of production (and possibly thus further standardization and modularization of technology). This mature phase of an industry may persist for sustained periods of time, particularly in industries with natural monopolies, strong scale advantages, high infrastructure costs, barriers to entry, etc. However, in more competitive mature markets, whenever incremental product innovations have been exploited and the productivity gains of process innovation have been realized, the profit margins erode quickly. This stimulates firms to engage in research for radical innovation to open up new markets, sell radically new products at higher margins, and follow new business models. This is Schumpeter's celebrated notion of *creative destruction*. When demand materializes, competitors follow, thus unleashing competition in the inception phase of a new cycle.

Incremental vs. radical innovation: *Two types of innovation. Incremental innovation concerns mere extensions of the existing design, consolidating the existing paradigm. Radical innovation introduces a new paradigm, generally a breakthrough increasing the performance in some dimension(s) in the order of several magnitudes.*

Note that, in general, *incremental* innovation comes about by extending existing technology in steps *evident to experts in the same field.* Whenever research and development merely extend the current products, it is essentially consolidating the current technological paradigm. In addition, entrepreneurs seek to leverage previous research and increase the returns on investments. With that, there is a risk that, at some point, research & development becomes essentially *locked in* into a particular technological paradigm.[9] It might even be so that particular rationales for design choices made in the past are no longer relevant but market inertia hampers switching to (superior) alternatives (e.g. the QWERTY layout of keys once picked to prevent jamming of the mechanical typewriters (David 1985)). Technological formats, designs, etc. may also be 'fixed' by double-sided markets and network effects (e.g. the VHS versus Betamax versus V2000 competition on the Videocassette Recorder market). Essentially, a *lock-in* can only be escaped by radical technological research & development, which has several challenges of its own, such as the high risks of failure, the first mover disadvantages (e.g. making high costs in exploration, while competitors can be imitated cheaply), etc.

9 Interestingly, while predominantly large corporations may have resources for research & development, they seek to further exploit their own technological paradigms. In contrast, entrepreneurial startups and spinoffs may actually seek means to overthrow the paradigm of incumbents. From an evolutionary perspective, a 'decentralized search' by a multitude of entrepreneurs, each searching within its particular technological space, exploring own ideas may decrease chance of industries getting locked-in.

Over the course of the lifecycle, the population of firms (consisting of both incumbents and entrepreneurs freshly swarming in) thus has evolving innovation targets. With that, also the collaboration propensity and (preferred) governance forms in innovation activities change (e.g. Afuah 2001). In the turbulent inception stage, entrepreneurs explore and experiment with product technology and as such rather stay vertically specialized to flexibly switch between potential upstream and downstream partners. In the mature phase, firms focus mostly on scale and low-cost production and incremental process innovation takes place mostly within the existing supply/ production network (e.g. Rosenkopf & Tushman 1998). The governance forms of firms in and dynamics of the production network is out of scope of this publication chapter.

6.3.2 Regional clusters, catching-up and falling behind

(Spatio-)temporal patterns: *Notion that type of research and development changes over the course of the industry evolution, notably cycling through breakthrough, exploration, design dominance, and exploitation phases. Moreover, also the location of research and development activities as well as the distance over which collaboration takes places may change over time.*

Given the changes over the industry lifecycle of the type of innovation activities (from product to process innovation), the shifts in the characteristics of knowledge (from tacit to more codified, from 'alien' to 'familiar'), it may well be so that also the governance form of collaborations and dynamics and structure of the innovation network changes over time. Indeed, apart from *temporal* patterns, there also are particular *spatial* patterns to be expected. Particularly during the inception stage of industry lifecycles and, more importantly, with the rise of the industry, much of the technological knowledge is still tacit, partial, fragmented, etc., such that face-to-face communication and intensive collaboration within geographical proximity may well be preferred. That said, the combination of knowledge for (breakthrough) product innovation is generally new rather than yet another incremental combination from likely knowledge sources. As such, knowledge is discovered and accessed from outside the existing network and possibly even outside the region in which the focal firms reside. If such alien technological knowledge is not found in the region/ cluster, it must necessarily be imported from a different region / cluster, imported through a pipeline and absorbed and used in a local buzz (Bathelt, Malmberg, & Maskell 2004). Subsequently, product designs emerge, knowledge becomes codified and embodied in products. With that, face-to-face communication and thereby co-location for exploitation and extension of that knowledge base is no longer strictly required (Audretsch & Feldman 1996).

This spatio-temporal pattern is, however, somewhat theoretical as there is, arguably, a strong moderating effect of the build-up of a population of actors (in one or competing production/ innovation networks), skilled labor pool, and collective knowledge base in a particular region, which is well-likely a gradual process. A prominent strand in innovation economic literature studies the geographical aspects of innovation and reveals how regional economic forces and externalities moderate the spatio-temporal patterns of innovation networks.

First, there are regional agglomeration externalities. By co-locating in the same region, firms within the same and technologically related sectors have access to a shared pool of skilled labor (which moves or already lives there or is provided by local education institutes), find specialized component suppliers (which also move to or rather emerge in the regions), and enjoy knowledge spillovers by mobility of personnel, informal contacts, etc.[10] Regarding the latter point, for reasons given before, co-location allows efficient absorption and creation of new technological knowledge (Asheim & Coenen 2005). While firms may thus actively move to particular regions to tap into knowledge, access the labor pool, etc., an additional cause of clustering of technological development is that spin-offs often stay close to the parent company,[11] and, similarly, academic start-ups may well stay close to the university.

REELER studied patent data and finds clear support for the agglomeration of robotics inventors in Europe: there is a particularly strong geographical clustering in several Baden-Württemberg and Bayern regions in the south of Germany, (*see Figure 6.2.*) Interestingly, these clusters seem to host innovation networks around competing system integrators or competing lead users. This is actually supporting the claim that agglomerating externalities are at work.

Note that regions may host a mix of firms developing robots for different market segments (e.g. manufacturing versus healthcare), may host firms from the apply sectors or not, etc.

That said, another REELER study revealed that countries may well be 'technologically specialized' in particular types of robots; while most countries have patents associated with robots for the (car) manufacturing sector, for instance, The Netherlands is specialized in robots for the agricultural sector (Spinoni 2018).

Second, although there are particular advantages of co-location (i.e. geographical proximity), the knowledge does only travel through channels. Indeed, there are still institutional or organizational ties required for the creation of channels for the exchange of technological knowledge (Boschma 2005). REELER case studies and also the REELER mini-public on agricultural robots revealed that robot development takes place in particular 'hotspots', with the consequence that access to technological knowledge may well be limited to actors in other parts of the world. It was, for instance, found that access to technological knowledge on agricultural robots is limited on the African continent (*see Annex 5 REELER Outreach Tools*)[12]. As such, innovation networks in regional clusters in developing countries may compensate the lack of particular knowledge, resources, and capabilities by nurturing a more global innovation network (Ernst 2002).

Figure 6.2. Density of the NUTS2 location of inventors patenting robot technologies (REGPAT data until February 2016). A darker shade means more inventors mentioned in patents are located in that particular NUTS2 region. A region is blanc if no inventors were registered in the REGPAT data. (Source: own data extraction and visualization, see responsiblerobotics.eu/annex-1)

Third, while breakthrough innovation initiating a new lifecycle generally requires 'alien' knowledge that often comes from 'outside' (at least outside the cluster, but well possibly also outside the region). That said, knowledge may also be acquired for mere application, such that knowledge transferred into the region need not necessarily target a breakthrough. A study of one of the REELER researchers (Vermeulen 2018) found that the distance to the ultimate sources of technological breakthrough knowledge increases over time, but collaboration of co-inventors in further development becomes increasingly local. The increasing distance of referenced knowledge sources is facilitated by, firstly, codification, and, secondly, diffusion. Before researchers and developers can access knowledge over longer distances, it is to be codified in patents, papers, presentations, embodied in products, etc. Moreover, time is needed for inventors, developers, and researchers to become aware of the existence of new knowledge, i.e. there is diffusion of information on the existence of knowledge. Note that, even if it is the (technological) knowledge itself that dif-

10 These are the Marshall-Arrow-Römer externalities, see e.g. Glaeser, Kallal, Scheinkman, & Shleifer 1992.

11 There is an emerging body of literature revolving around some hypotheses of Klepper, see e.g. Berchicci, King, & Tucci 2011.

12 see responsiblerobotics.eu/annex-5 and see responsiblerobotics.eu/outreach

fuses, there are formal and unwritten rules that references are to be made to the original source (e.g. patent citations, paper references). The increasingly local collaboration of researchers and developers is due to 'technological localization' (*see also Section 6.1.3* on technology transfer), i.e. the increasingly applied character of technological extensions, integration with existing technology, adaptation to local environments (e.g. in terms of language, culture, practices, beliefs, etc.), catering to local market preferences, technological appropriation, etc.

Fourth, the development of a region/ cluster may be 'path dependent'; knowledge development is cumulative and follows particular technological trajectories. Search directions and hence new discoveries are both deliberately as well as unintentionally extending existing technology (by recombining knowledge that is known), building upon a certain technological paradigm (Dosi 1982). Such that *path-dependency* in technological knowledge development happens to both individual inventors, to companies, as well as clusters and regions. Whenever firms experience dwindling profits, decreasing demand, etc., they may seek to enter new markets or even engage in radical innovation to create a new product-market (*see section 6.3.1*).

Path dependency: *Tendency of new technological knowledge to build upon and be compliant with the extant, surviving technology paradigm.*

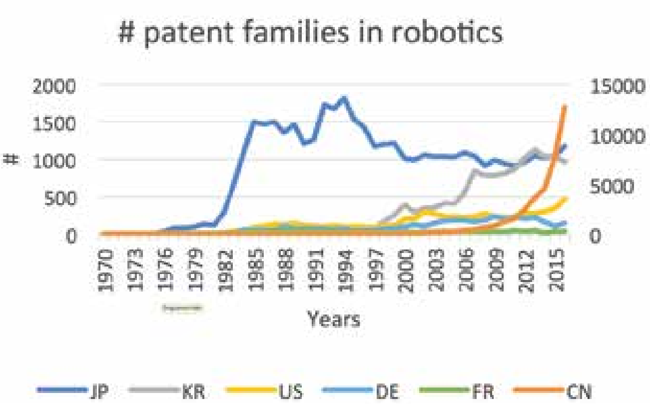


Figure 6.3. Number of patent families in the PATSTAT dataset. The scale on the right axis applies to the number of Chinese (CN) patents, while the scale on left axis applies to the number of patent families of the other countries. (Source: own data and elaboration, see responsiblerobotics.eu/annex-1).

Due to path dependencies, resistance to innovation, and technological lock-in, clusters may fail to keep up or untimely see the urgency to do so, thus falling behind competing clusters. Famous examples are the Detroit and Ruhr areas. On top of that, there is structural change in the sense of 'de-agrarization' and 'deindustrialization', such that particular clusters are bound to be dissolved. That said, while there was a substantial amount of patenting of robotics inventions, particularly by Japan, USA, and Korea in the past, but nowadays this is completely eclipsed by a surge in the number of Chinese patents, (*see Figure 6.3*). Although it remains to be seen whether these patents are part of a 'thicket' to obstruct rivals or actually lead to innovations, it is clear that China is accumulating knowledge and competences that may constitute a threat to the traditional clusters in Japan, South-Korea, the U.S.A., and Germany.

6.3.3 Technological change and social construction

This chapter has focused mostly on the process of technological development from the perspective of either the robot developers or robotics company, thereby implicitly assuming the stakeholders and notably customers, but also society in general, have relatively fixed, immutable albeit unknown requirements. So far, the agenda of research & development activities of robot developers was largely determined by the goals of product development, defined by the technological role in innovation networks, and as has just been introduced, the (bursty) accumulation of technology in the robotics(-related) sector(s) over the course of the consecutive industry lifecycles. However, particularly over the long-term, there may be considerable changes in requirements of customers, the application environments, expectations and (public) opinions of stakeholders, the institutional and infrastructural arrangements, legal and ethical conditions, policy instruments in place, etc. So, society evolves and in part even due to the introduction of the focal (and possibly impactful) technology.

Economists started out picturing technological change as a process in which technology was first invented ('new to the world'), then innovated (i.e. tailored to commercial use in a particular, new market), and then diffused (i.e. spread across both producers and consumers through imitation). Similarly, it was pictured as process in which academics conceive scientific concepts (fundamental research), developers subsequently materialize these concepts into technology (applied research), and entrepreneurs finally bring the technology embedded in products to the market. Gradually, economists refined this perspective by moving away from a process with discrete, consecutive stages, to an involved, non-linear process in which experiences with application or actual use feeds back/ forward to innovation and invention activities, e.g. adapting the technology or leading to new product developments. In some cases, entrepreneurs initiate research & development because there is a clear market demand (e.g. medication and treatment of diseases), i.e. there is market pull, while in other cases, entrepreneurs 'push' technology and rather create a new market (cf. Steve Jobs' supposed quotation "A lot of times, people don't know what they want until you show it to them").

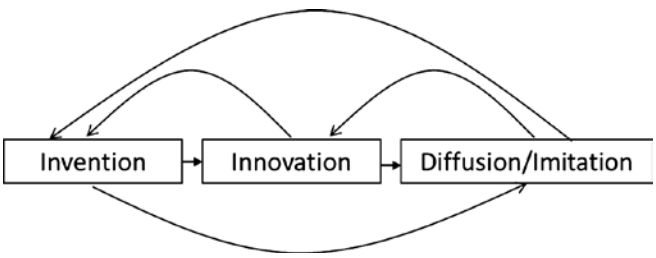


Figure 6.4. Non-linear model of technological change

Similarly, there is a non-linear relationship between basic and applied research. Basic, fundamental scientific research conducted at universities and public research institutes does not necessarily precede applied research undertaken by companies. History is littered with examples in which the scientific understanding was developed only after practical applications emerged or were even well-established (e.g. the steam engine was widely used before thermodynamics was understood).

Such long-term technological change and evolution of society and the economic system is (also) the domain of scientific fields like the history of technology, and science technology and society studies (STS). For instance, how harnessing electricity generation and transmission led to (i) emergence of public utilities, (ii) sectors for home appliances, machinery, tools, etc., (iii) electrification of buildings and the public space, (iv) development of a wide range of other technologies and enabled a multitude of new services, (v) radical changes of work, recreation, and leisure, (vi) opened up new scientific fields and changed others. While it remains to be seen whether robot technology will be this impactful, it may also lead to various new sectors, permeate daily life in households, factories, offices, public space, etc., enable providing new services, radically change work and recreation, etc.

In fact, it may be argued that robotization of society is part of the techno-economic paradigm (Kondratiev wave) started in the 1980s (Perez 1985) with -in retrospect- a cascade of innovations based on microchips, software platforms, mechatronics (i.e. the fusion of mechanics, electrical engineering, and embedded software), digitalization, communication technologies including internet, etc. Arguably, at present, there is a wave of further technological recombinations leading to interactive robots, artificial intelligence, block chain, Internet-of-Things, etc. which are applied in a range of sectors under headers such as Industry 4.0, Agriculture 4.0, Healthcare 4.0., etc. The introduction of these technologies brings new business models, requires new institutional arrangements, upsets social and economic conventions, etc. Moreover, new application concepts also feed back into design requirements. For robot designs, this goes as far as progressive integration in complex socio-technical environments requiring sophisticated interaction with humans (e.g. reading facial expressions, predicting movements, speech recognition), advanced technical interoperability (e.g. communication protocols, data recombination, flexible information systems, swarm robotics), comprehension of complex, variable, and ill-structured environments, etc.

As outlined in section 6.2, modern innovation economics distances itself from any linear, hierarchical, deterministic view. Instead, it perceives technology development taking place by knowledge-based collaboration of a heterogeneous network of entrepreneurs, research institutes, government, pressure groups, and other types of economic actors. Such innovation networks evolve endogenously over time, with autonomous actors entering, refocusing, and exiting, hereby also driven by emergence, maturation, transformation, and dissolution of their segments, etc. Moreover, activities of robotics firms are affected by the competitive nature of the industry.

Ambitious (prospective) robot developers, may well not only be considered how such (big, long-term) changes affect their immediate research, development & building activities, but they may also be motived by their contribution to the betterment of society and may in fact actively market themselves so. Moreover, not only the market but also funding agencies may reward such a 'socially responsible' attitude. From a meta perspective, Horizon 2020 funded projects such as REELER and INBOTS to study how to enhance the socially responsible and ethical design of robots (Perez 1985).[13] Both projects seek to do so largely by advocating for, raising awareness on, and providing tools to incorporate societal concerns in robot design and application.

6.4 Concluding remarks on Innovation Economics

In conclusion, this chapter analyzes the process of researching, developing, and designing robots over short-term 'new product development' processes within endogenously evolving innovation networks facing industry lifecycle challenges, long-term technological change, and a changing society.

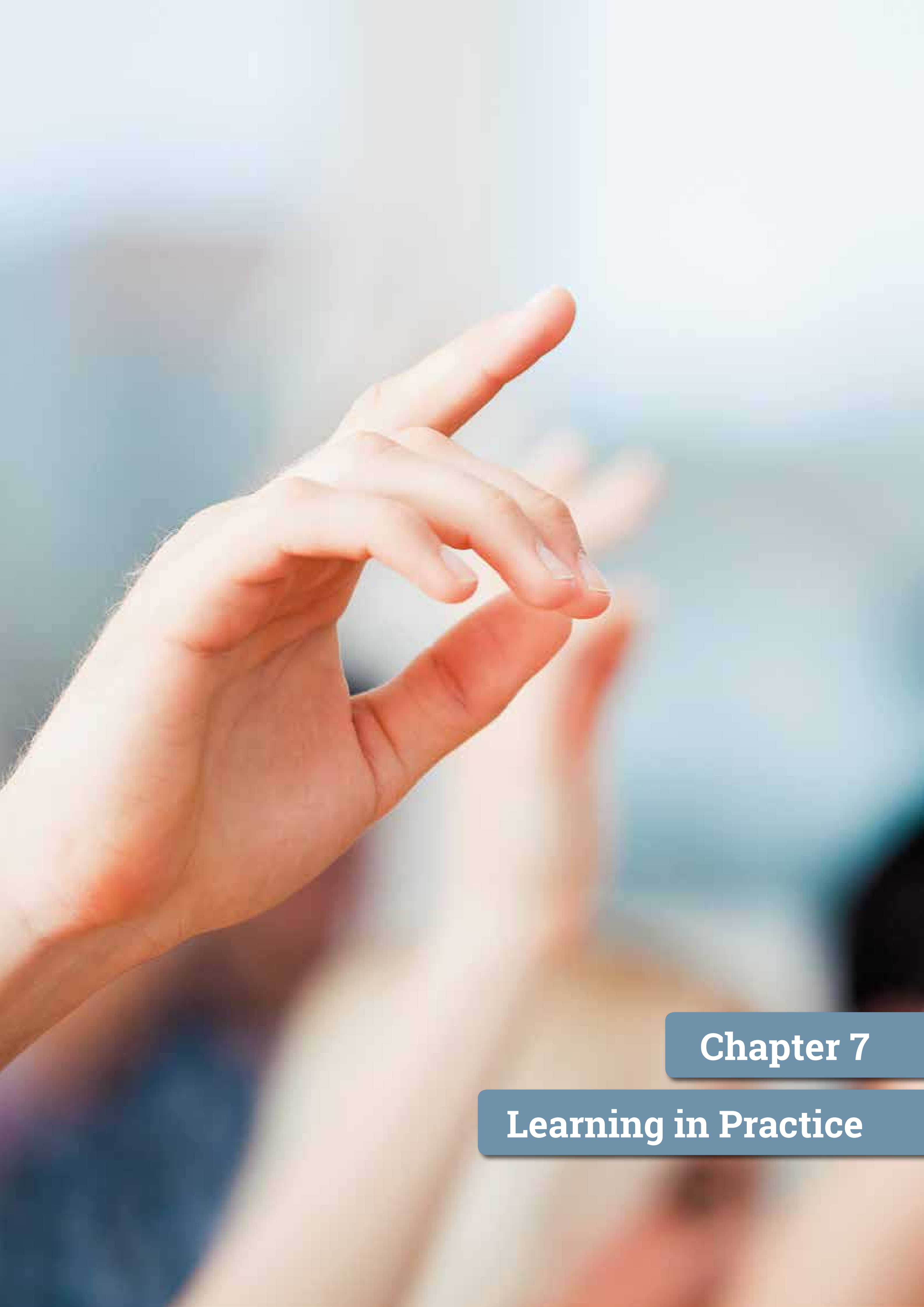
We adorn a stylized new product development method, notably recognizing that robot developers have to (i) sequentially 'bootstrap' out of a situation fraught with market and technological uncertainty, (ii) modularize robot designs and iteratively and recursively solve technical bottlenecks therein, and (iii) conduct repeated develop-test-plan cycles thereby possibly extending the set of stakeholders involved over time in a staggered fashion. Moreover, often, robot development is done by a group of roboticists distributed over economic actors across space and time. In this, the roboticists have to cope with limited control over the, generally, decentralized development process, artifacts passed down without context, etc. In addition, these roboticists are restricted by the resources, capabilities, and boundaries of the firms and institutes employing them as well as the nature of the possibly relatively durable, (in)formal relationships of these actors. Conversely, resources are mobilized, capabilities developed, and relationships established on the basis of robot developers' current vision, technical challenges, etc., which are themselves outcome of previous activities. As such, there is co-evolution of technical specification and materialization of user requirements, and the innovation network spanned by the collaborating economic actors. Given the risk of thus getting technologically locked-in, innovation theories are emphasizing the significance of exploration of technical solutions as well as potential partnerships.

On top of these short-term micro-level and medium-term meso-level determinants of research, development, and design decisions, there are various long-term determinants as well. After all, there are consecutive industry-wide lifecycles pacing

13 INBOTS (http://inbots.eu), a Horizon 2020 funded research consortium, is developing and promulgating a framework for socially responsible robotics.

product and process innovations driving scattered accumulation of technologies as well as growth and diversification of sectors of application.

In fact, in addition, at the meta-level, there is scientific progress on new product development methodologies, emergence of strategic management and innovation management paradigms, and progressive insights in societal aspects and human factors to be taken into account (e.g. human-robot interaction), etc. Arguably, REELER is actually contributing to the latter by imploring robot developers to now also properly include a wider circle of stakeholders and incorporate ethics in design considerations (beyond the usual safety, security, liability, ergonomics, etc.). Hopefully this chapter also showed that we are well-aware of the (fundamental) challenges robot developers face and provided conceptual ideas on how to cope with them.



Chapter 7

Learning in Practice

”

You have to learn this: What are the positives and what are the limitations? So, I should not have this idea that the device can do anything [by itself]. That will never be the case I mean, if I know it, then I can use it, but it's a matter of learning! You see, I have to know the device, and I must be able to analyze human movement.

(Viktor, physiotherapist, affected stakeholder, REGAIN)

7. Learning in Practice

How what we know about robots and humans matters

You will find here

- Definitions of knowledge, learning, and education and the naïve user
- Presentation of the types of learning undertaken by users and robot developers
- Presentation of problems with training
- Practical examples of learning in situ (every day on-the spot-learning)

You will acquire

- Awareness of learning perspectives in robotics
- Awareness of educational biases
- Awareness of educational contradictions
- Awareness of situated in-situ learning
- Awareness that naïveté is relative

In a micro-perspective REELER has found that whenever robots are attempted implemented, a learning process begins and continues on an everyday basis (*see Bruun, Hanghøj and Hasse 2015, Blond 2019*). In fact, even for robot developers themselves, learning is an ongoing process. However, the relation between what the robot can do by itself, peoples' knowledge of robots, educational background, and the situated learning taking place when robots are implemented are at present not well understood. It also raises political questions: Who is to provide the workers with the necessary skills to operate the robots? How do we ensure the right kind of upskilling? And do robots risk amplifying educational inequality? These are some of the questions dealt with in this chapter.

As Viktor states above, in order to understand what the rehabilitation robot he is working with can do, he needs to get to know it in a situated practice. For the purposes of this chapter, *knowledge* can be defined in a broad sense as a corpus of conceptualised ideas about the world codified (as words, pictures, symbols) for communication through social and material relations (Barth 2002; Hasse 2015; Jöns, Heffernan, & Meusburger 2017). *Learning* can be defined as the process of developing this corpus through engagement with a social and material world (*see also 1.0 Introduction*), and *Education* as the social infrastructure and systematization of learning (often for some other end). All of these terms represent ways of understanding the world, and are useful in describing how people develop and adjust their understandings of the robot, of each other, and of the world as it changes.

This chapter will present these three aspects of human learning with regard to robots, drawing on the ethnographic data from REELER:

Knowledge:
1) How new information about robots affects both robot developers and users' acceptance of robots,
2) How new information about humans affects robot developers' design and implementation decisions.

Learning:
1) How humans learn to adapt to robots,
2) How developers learn about the users and the robot in the context of use.

Education:
1) How increased robotization and automation place new demands on education, including ethics in engineering education,
2) re-skilling the workforce (who can be reskilled, technological literacy, dyslexia), and
3) the increased need for "learning to learn" in order for workers to remain relevant in an increasingly automated world.

7.1 Knowledge

This section covers how information about robots affects acceptance, and how information about humans affects design and implementation. **Knowledge** is an accumulation of conceptual ideas about the world that a person forms through transformative experiences engaging with the material world (i.e. learning). A person's past experiences frame their future engagement with the world because learning transform perceptions (e.g. Hasse 2015). Acquired knowledge, or lack of knowledge, shapes a person's perceptions of robots (*read more in 8.0 Imaginaries*), and can affect how robots are designed, how they are regulated, and how they are taken up or resisted (Nickelsen 2018). The robot makers in the REELER project are not all developers (the group also comprises policymakers, representatives from funding agencies, economists, biologists, and even psychologists), but most have a background in engineering. Their knowledge about robots has been developed and consolidated over many years in educations such as mechanical engineering, but also more specialized areas like bio-engineering and industrial engineering. They know so much more than affected stakeholders about their technical tools and about technical problem-solving (Barak and Zadok 2009), and often they describe and care about a particular technology as an isolated phenomenon and often do not consider environments or the wider context.

Knowledge: *A corpus of ideas about the world which is codified (both as concept and as words, pictures, symbols and other material externalisations) for communication through social relations.*

When a person has real-life experiences with robots, their fears become more realistic. (Photo by Kate Davis)

7.1.1 The naïve human

Opposite the knowledgeable developers we find what some robot developers define as **'naïve humans'**. While the term seemed puzzling and somewhat offensive initially, we soon found out that robot developers do not intent this term to be derogatory. It simply refers to inexperienced users, whose experiential knowledge of robots is limited, and whose imaginaries are informed by popular, non-technical (and sometimes inaccurate) information that may peddle fears and uncertainty with change, which frames their orientation towards technology (Nilsen 2016).

Naïve human: *A term used by robot makers (and computer scientists) to refer to persons unfamiliar or inexperienced with robots (or other digital technologies).*

When a new robot is introduced among "naïve users" (Kennedy 1975), technological apprehension may limit the user's ability or willingness to engage with the robot.

Technology apprehension: *An initial reluctance to use a new technology, tied to a lack of experience or lack of information.*

I am entirely sure that there are some who won't use [the robot], because they don't dare.

(Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

Enabling users to observe a robot in use can provide the users with situated knowledge that may alleviate some of their initial apprehension toward robots.

STORY FROM THE FIELD:
How lack of knowledge can elicit fears

Elif works at a hospital in Northern Europe cleaning patient rooms and common areas. She has worked with cleaning machines and other advanced cleaning technologies, but has no experience using or working near robots. Her working conditions are good: her work is well-paid, she has peers who support her and a boss who listens to her, and she enjoys a fair level of autonomy in planning and executing tasks. She is very content in her work and is confident that machines cannot do the complex work that she does. Nevertheless, when asked how robots might impact her life over the next decade, Elif has a grim outlook.

"It [robots] will. It definitely will. It will change the entire world - not just work days, but also private days. It will, for sure. It will destroy it all, I think. It is going to destroy it all."

Elif's fears about robots are tied to her conceptions about what a robot is. She does not have real-life experiences with robots, so her imaginaries are informed by entertainment and news media., and she has little to no information about actual robots used in workplaces. When REELER visits her workplace, Elif is introduced to a robot that is still under development, but intended for use in hospitals and other industrial settings, cleaning floors and surfaces. Elif is given detailed information about the robot, its weight, risks and safety features, and she watches videos of it in use. When asked to reflect on this particular robot, Elif says:

"I think it is quite nice. It is a good idea. It is positive. I am positive now. Initially, I was very cold. I said no. But now, I have looked at the video, and I think, it is very important that it kills bacteria. And so it changes my mind, actually. Yes. It could be a good idea that we got it."

When asked again how she feels about robots in general, and a human future with robots, Elif no longer feels robots will *'destroy it all'*. Her new experiences (her exposure to new knowledge) changed her perceptions of robots to more realistic or grounded understandings, and as a result she is more open to new experiences with robots.

(Based on an interview with Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

As demonstrated in the story about Elif, **technology apprehension** related to general fears or concerns can be mitigated to a great extent when a person has access to basic knowledge about the particular technology at hand (Hasse 2017) or when they get to see it function in practice.

It is also here naïve robot developers stand to gain from engaging with everyday workers like Viktor and Elif, who have a **situated knowledge** about what works in manual processes. This situated knowledge can be explained, but often remains tacit. It has often been learned without any explicit education involved and it is therefore an effort to put words back on the knowledge that has been learned.

Situated knowledge: *Knowledge acquired through social engagements in a particular activity, context, and culture in situ i.e. (at local sites).*

While workers may be naïve about robots, they far from naïve when it comes to understanding the ins and outs of a particular task. In fact, some of the most reflective robot developers are fully aware of how much they can learn from users at local work sites.

I think the biggest challenge we've met has been that every time we've visited a construction site, we've encountered something new. Fully understanding what goes on in these sites is very difficult. Even our extensively thorough pre-analyses are being put to shame, because what we're competing against is a craftsman, often a specially trained one at that, meaning they are using their hands in ways that we can almost never fully register. We've even tried taping them, but there's still a lot of things going on that we don't see. On one occasion we were putting up a small element, one of the workers commented that it was a bit crooked, but before I even had time to consider it, two of them had walked over, done a little dance, and that was the end of it. As soon as they had seen what the problem was, it took about 3 seconds. They're trained to solve problems as soon as they arise, no matter the cost. The show must go on. To pick up on all those details, that's a tall order. That is one of the biggest challenges we're facing. Maybe we ought to send a staff member there for six months or so, but even then, we'd likely see differences between the individual construction sites. Most of the sites we've visited have been major renovations or new constructions, not a big difference in this context, but there are still a lot of differences from site to site.

(Valdemar, engineer and CEO, robot developer, WIPER)

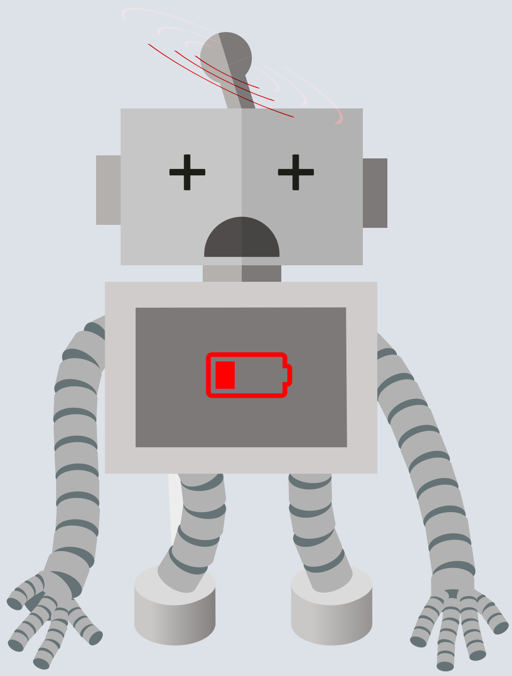
In this quotation, Valdemar puts into words the tacit processes of construction work and illustrates the complexity involved in emulating such processes in robots.

7.1.2 The resistant user

As familiarity with a technology increases, instead of a general fear of robots or technological change, a user may become aware of the particular challenges one meets when working with that specific technology. When the user experiences the robot as a threat, for example to their wages or their identity, a new type of technology resistance may pop up (Nilsen 2016). Technology resistance differs from technology apprehension because it is based on real learning experiences rather than imaginaries (*see 8.0 Imaginaries*). Left unaddressed, this resistance may even lead to non-use, misuse, or sabotage (*see 10.0 Meaningful Work*).

Technology resistance: *Opposition to an implemented technology, whether by passive non-use, active misuse, or deliberate sabotage.*

STORY FROM THE FIELD:
Technology resistance



A construction company approaches a robot developer with a request to co-create an assistive lifting device. The purpose is to comply with labor regulations that are in place to protect workers from the risks of heavy lifting, and to reduce human labor. Working in close cooperation with the construction company and construction workers, the robot developers test the intuitive robot at real building sites. The robot is on a construction site for some time before the developers are notified that it had been operating poorly. Werner, one of the robot developers, explains that his team *"talked to the foreman over there. 'They [construction workers] have run it and installed some doors with it,' he said. Well, that was good. Then two days later we talk to him again. Well, they thought it was running strangely, so they had just put it aside. They didn't want to run it any longer. 'Okay,' I said, 'we will come pick it up Thursday'. And then, when we got there, the workman says: 'We haven't run it all.'"*

During the testing of the robot, the developers met some resistance (non-use) based on the users' experience of the technology in use. The users recognized the demands the robot placed upon them and their workflow, and they resisted these demands by abandoning the technology.

"What actually happened was someone had tried driving it down the hallway and it was all wobbly. One of the guys had tried installing a door, and that had been tricky and then he had just given up. And then it stood there. So, they hadn't even, like –they didn't inform themselves, or whatever," Werner notes.

Though co-crating the robot, thee developers had overlooked the demands the robot would put on the workers, because, from their own experiences, the design was user-friendly. Put differently, the developers learn that the users experience their robot differently from themselves. Their intuitive assistive device was perceived as 'wobbly' and 'tricky', and would require a great deal of learning and adaptation. This clashes with the workers' expectations and conditions for performing their job and hence they decide not to use it.

(Based on an interview with Werner, operation and production technologist, robot developer, WIPER)

Learning in situ can counter imaginaries (typically informed by science-fiction or news hype) and lead to reduced technological apprehension and greater acceptance (Nomura et al. 2008; Turkle 1986), as was the case with Elif. However, as users gain more situated knowledge through use, and their imaginaries become more rooted in lived experiences, resistance may emerge again (de Graaf, Allouch, & van Dijk 2017); this time from tangible issues that the robot developers may actually have an opportunity (or responsibility) to address.

Thus, knowledge can be a powerful instrument in bringing users' imaginaries about robots closer to the actual robots they might encounter in their everyday lives, and it may decrease fears and increase acceptance of robots in general. Specific knowledge about a particular robot may also reveal issues with that technology which could lead to resistance, if left unresolved.

7.2 Learning

This section presents data from REELER on how the humans in our study learn to adapt to robots and how robot developers learn about the users and the robot in the context of its use. Learning is the process that organizes knowledge and know-how in recognizable patterns (also known as 'cultural models' – see Hasse 2015). We form expectations, habits and meaningful perceptions on the basis of learning. In this respect, knowledge (what we think we know) and know-how (our ritualized embodied unreflected knowledge) are continuously transformed as we learn (Hasse 2015). Colloquial learning is often tied to education, and education, of course, matters for the kind of knowledge one organizes. In the context of REELER, learning is more than what goes on in formal education. It is a process that provides us with situated knowledge about our social and material world on a daily basis. Learning, making sense of the material world, is the social process by which we acquire knowledge of what to expect (D'Andrade and Strauss 1992).

Whenever a new technology is put to use, a new learning processes are initiated that teaches us about how the technology fits (or does not fit) with our daily routines.

Organized learning: *The process of developing organization of knowledge or know-how through engagement with the social and material world.*

There are four particularly relevant areas of learning occurring in robotics between humans and machines:

1) Users learning to adapt to robots, to meet the demands the technology places on the human.
2) Developers learning about their robot as a technology-in-use, situated in a context with actual users.
3) Collaborative learning, learning what is important to each other and aligning motives to work toward a common goal.
4) Workers learning to learn, in order to remain relevant in an increasingly automated world.[1]

All of these learning areas are best understood from a perspective of **technology-in-use,** which bears with it the importance of situatedness, which is a theoretical concept developed by Jean Lave and Etienne Wenger (1991) to explain how learning occurs as a product of social engagement in a particular activity (e.g., using an assistive robot to install doors in new construction). Situated learning is practical and social – *it is not* formalized training or education, nor is it an individual mental activity (Lave & Wenger, 1991, p. 49). Further, the learning occurring is shared or distributed in the community of practice, meaning that learning is inscribed in the social and material practices of the context (Hasse 2015). Going back to the story from the field about technology resistance, when the workers discovered that in their particular site the robot became wobbly, it became a particular situated knowledge. In other situated contexts, the relation between the (maybe more plain) ground and the design of the robot would not have been a problem. However, these workers also came from a culture where they speak out, and react directly when unsatisfied, whereas in other cultures workers may put up with more. To treat the situated knowledge as divorced from the context would be to render it meaningless (see examples in the discussions that follow).

Technology-in-use: *An understanding of a technology not as a static object, but as a thing defined and redefined by its context of use.*

Therefore, "enhanced technological literacy [for both users and robot makers] must include an awareness of how 'engagement' changes when technologies are used in situated practices" (Hasse 2017, 370), as seen in the resistance example in the previous section. Situated learning occurs both among users beginning to work with or alongside a robot, and among robot developers learning about users and their robot in the context of use.

7.2.1 Users learning about robots

A lot of learning in situ is required to make robots work, even when designed in the laboratory to be user-friendly or intuitive. On the surface, users must learn how to operate or interact with the robot. This can be a hard task for the worker when they have to learn by themselves how to operate a robot, e.g. through a tablet. In this story told by a company owner, a metal worker, who was previously considered a good worker,

1 It could also have been relevant to include how robots and AI 'learn', i.e. how machines adapt their own behavior (output) based on the data they acquire (input). This point does not relate to human learning, but learning in machines. Because we recognize irreconcilable differences between human and artificial intelligence, and because machine learning was not an explicit target of the REELER project, we will not address non-human learning, however see Hasse 2019 (forthcoming).

was all of a sudden under scrutiny by management because he began to make serious mistakes.

> *Well, you hire a 50-year old Russian, who is a really good metal worker, a good person as well. But now, I try to teach him that on a touchscreen, he has to register this [order to the 'printing' robot], and re-register that [order]. Everything stands and falls with him. If he doesn´t scan, then the system says we still need to make a thousand pieces. I need this much capacity, and so forth. So, what also happens is he scans wrongly. He makes 50 and scans 70 and closes the order. Then, after that starts to ship, [the system] says, '20 are missing'. This simply is a system that says 'nope' [laughs], 'those [missing 20] are finished, they should be with you.' It then searches for them in the whole place and says, 'they are not finished.' Just because one person scanned wrongly! You know, these are the kind of issues, basically, where the theory is clear and where everyone knows why we are doing it. But your workers, you have [the worker] who is a simple metal worker who wants to do his job. He says, 'What is it you want with it? How? What is it I have to do?' And you need to teach it to them, and there are different people as well. The first is open to it, since he already has a smartphone, and you have to prevent him from playing with his smartphone. And the second has a problem when entering three digits on the touchscreen.*
>
> (Karl, SME owner, affected stakeholder, COBOT)

The 'simple' Russian worker that Karl is telling about had to learn new things on-the-spot in his situated practice because this practice was changed by new demands introduced by the robot and its operations (*see also 4.0 Ethics Beyond Safety, section 4.1.2*). This type of learning is sometimes addressed by training (online or in-person), through user manuals, or in tutorials built into the interface itself. At other times, the robot is sold off-the-shelf as a plug-and-play solution – its assumed intuitiveness rendering training unnecessary.

Depending on the type of robot and application sector, the need for training of staff before or during implementation varies. However, the more we move into industrial areas and bigger industries, the more we find that employers recognize the need for official training (particularly in the cases OTTO, COOP, and some robots in COBOT). Here, the robot developers and companies often work together to provide training. These kind of training programs can last from a day to several weeks, and in one case with follow-ups several times a year. This might be explained by a long history of automation and system integration in production sectors.

Yet, when we speak to the workers' Unions, we hear tell of disagreement about who should be responsible for training. Arne is a district Union secretary in one of the largest countries in Europe, with many robots in the industrial sector. He explains we should recognize that different workers have different needs for reskilling and training, when robots are introduced in the work life.

> *Arne: "Well, we should of course understand that employees have different experiences, are of different ages as well, and are different in how open they are. Even today, some of the older people are saying: 'Keep those computers away! I haven't received much training in the recent years, anyway.' He won´t scream 'hooray' in front of an e-learning platform. Others are more used to it. There are many different starting conditions. One has to take this into consideration, that it is different for each person. Don't create a digital divide with this [new technology]."*
>
> *Interviewer: "Is training popular in general then? Do the employees want to receive training? Or do they think that it is annoying and irritating?"*
>
> *Arne: "I believe, this is very different as well. The guy who says that he is going into retirement in half a year, he probably won´t be very open for training because the period of time for actually using this is too short. Whereas a younger employee will benefit from it. I primarily believe that the employees are open to it. I notice a contradiction here [in relation to] the qualification, training, lifelong learning – namely, that the employees are being forgotten if they are on the lower levels of the hierarchy and do not have many qualifications. [The training and qualification] is being made for those, who already have a lot, and we have to think more about how we, in the area of trainees and unskilled employees, can facilitate qualification offers for those people [as well]. This would otherwise be a contradiction, if one only always focuses on the few."*
>
> (Arne, district union secretary, affected stakeholder, COBOT)

Whether or not learning is anticipated, the amount of learning that takes place in implementation goes far beyond learning to use the device. Looking more closely, humans must learn to adapt their routines, behaviors, and environments to accommodate a robot (Bruun, Hanghøj, & Hasse 2015) (*see also 5.0 Inclusive Design*). For example, a patient using a feeding assistance robot may need to learn to tilt his head in a particular direction to receive the awkwardly angled spoon; or, a care professional might need to learn to use sticky porridge-like foods, but not loose food like rice. Making these small adjust-

Rapidly-changing technologies place new demands on the workforce, requiring reskilling and ‘learning to learn’.

ments –also called tinkering – is necessary for the robot to fulfill its intended role (Nickelsen 2018). Understanding the use of robots as situated is to acknowledge that robots are relational objects, which do not do the same work alone that they do with human interaction (Sorenson 2018). If the patient did not tilt his head, or if the care professional did not alter her meal plan, the robot would not be as effective. The users learn to make these adjustments through actual engagement with the robot.

Sometimes, users go one step further and learn to adapt their environments, and in some cases the robot itself. The same feeding assistance robot, BESTIC, can be mounted on a user’s wheelchair. However, one user experiences that mounting the robot precludes their use of another device used to access television and other media. BESTIC takes up space normally devoted to the television controller, and so the wheelchair setup requires the removal of a device that the user values. Thus, the user cannot eat independently (with the robot) whilst watching television, and consequentially has to learn to adapt his physical and social environment (Nickelsen 2018). In the case of Silbot, the eldercare robot developed in South Korea and implemented in both Denmark and Finland, the robot itself is reprogrammed to include more culturally appropriate interaction after having been rejected by users for using an overly disciplinarian style of communication that clashed with the new users’ more passive style (Blond & Olesen 2019) (*see also 6.0 Innovation Economics*). Rather than learn to accept the new communication style, the application experts choose to adapt the robot to the existing cultural context.

Whether learning to adapt one’s own conduct or lifestyle, the surrounding environment and physical setup for the robot, or learning to adapt the robot itself, the learning goes far beyond an orientation to operating the robot.

STORY FROM THE FIELD:

Learning in practice with a robotic wheelchair

Many rehabilitation centers in Denmark are using robotic wheelchairs in rehabilitation. In one case, the robot is too complicated for the staff to use. This is not due to the robot in itself, but related to the space around it. As a result, the robot was simply put aside for a long period of time. REELER speaks to Nina, a physiotherapist with experience with the particular robot, and she explains:

"At first, the poor robot was in another room, in another department, and it was forgotten. It was forgotten by the department, both the nursing staff and the therapists. It wasn't as easy [as with another robot], because you had to put the patient in a wheelchair, and then go all the way down [through the building]. So it was a big task in terms of planning. We also had to set aside those rooms to make room for it, even though we were under a lot of pressure already. Because it is very visible here, it isn't as forgotten as it used to be. Back then, it was only used once every three months or so."

There can be many reasons why staff give up learning to use a technology. It can discourage use, if simple things like the electrical system and batteries are not working when the robot is attempted implemented. Britt, one of the directors of the rehabilitation center, notes that:

"The technology needs to be so stable that it doesn't turn off every other time if it dies all the time, then it'll be a strain instead of, what's it called 'a help'. There are quality requirements for the technology to communicate with the computer [for example]. If it's through a cable or if it's something to do with WIFI, then you need to make sure that all those things are in working order, so the technology at least runs reliably."

Nikoline, another physiotherapist who also has experience working with rehabilitation equipment, including the robotic wheelchairs, underlines that for users to want to use a technology "it should be unmistakable what to do". Even when the robot is designed to be intuitive, and is actually used in situ, it can still be a steep uphill learning process for the individual worker.

"Of course they [the staff] have to learn some stuff and they also need an introduction to what all the functions do and what to do if it breaks down. They have to learn that if [they] have to set it up, and if there's a mistake in [the] settings, how do [they] calibrate it again. Of course they need an introductory course to the technology and what parameters you need to change in different situations. They obviously need a course in that when they implement the technology and they need time to become familiar with it before they are going to see citizens", Nikoline explains, and continues: *"But the actual settings need to be simple as well. Obviously you need to be able to change the different relevant parameters, but it needs to be very intuitive: "What is the first thing I need to adjust? Is it the shoulder joint I need to begin with, and then the elbow, and then the wrist or what is it, and what screws do I need to start with?"*

Formal training is necessary, but formal training must also take account of the situated learning that goes on in everyday practices. It may seem easy for the robot developer to imagine what is 'intuitive', but if the necessary situated learning is not intuitive in the same way, it can become so challenging for the staff that they simply give up, Nikoline explains:

"If she [staff] started screwing those on the chair so the height was right. Then after step one was 'place the screw so it fits the citizen's arm', and step three 'Now you need to adjust this joint', so you are guided through it, because it's not impossible for them [the staff] to understand technology and adjust it. It just needs to be simple and intuitive. If you haven't seen a citizen that use [the wheelchair] for a month and a half, and you come back and haven't used it for a month and a half, then you need to be able to get a sense of it again pretty quickly: 'What is it I need to do now?', because you have so many different citizens and the problems that the citizens come with are different."

However, Nina also stresses that, if the training and subsequent situated learning is a success, the robots are no longer 'forgotten':

"We may have had such concerns at first when we bought it: 'Will ever be used?' Because we hadn't discussed whether to buy it or not. But once we've been trained in its use, and things like that, and people have seen it operating, it's been really good."

(Based on interviews with Nina, physiotherapist, Britt, director of rehabilitation center, and Nikoline, rehabilitation therapist, affected stakeholders, REGAIN)

7.2.2 Developers learning about users

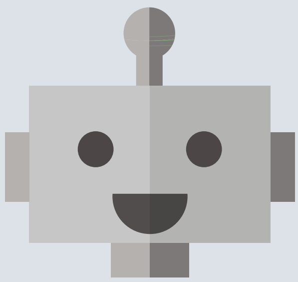
Developers must also learn about their robots as technologies-in-use; that is, they must learn to see the robot as situated in a particular application context among particular users. A robot developed and tested in laboratory settings is likely experienced completely differently in use elsewhere in the world. For example, a healthcare robot developed in Northern Europe is operated using a tablet interface that should hang on the door of a patient room when in use. The tablet was initially mounted to the door by magnets, until the developers learned that some doors are made of glass and hospitals may not want to modify their doors. To account for this new knowledge of different contexts, the developers opted for an alternative over-the-door hook, designed for doors of all materials. However, after implementation, the developer learned that some users are shorter on average in certain parts of the world, so the developer had to adapt his thinking and design again to accommodate the new information. Here, Oswaldo explains how learning about contextual differences can be accommodated into designs:

> *Yeah, we have had an issue in Asia, because depending on the type of door, we can use a metal plate and some magnet on the tablet. If the hospital doesn't want to modify the doors, then we have a hook that you hook on top of the door. The people in this particular country are too short to use this hook. And that's funny because when I designed it here, I already tried to make it longer because I imagined that maybe the people will be short but it was not long enough. And that's a bit crazy, but I mean that happens sometimes.*
>
> (Oswaldo, industrial designer, robot developer, SPECTRUS)

This learning in real-life test environments and implementation settings demonstrates the importance of understanding robots as technologies-in-use. Engagements with users and the robot situated in an actual or potential implementation site can open for learning about users, and what matters to them.

STORY FROM THE FIELD:

Learning what matters to users



In the development of the mounting robot used at construction sites, the developers were left with questions about the workers' resistance to implementation. Implementation at this site consisted of a demonstration and an explanation of the 'quick-start guide', but did not include on-the-job training. The developers went to another testing site where they worked alongside users to help them really get hands-on experience with the machine while the developers were available to facilitate the users' learning. Werner, one of the robot developers in the WIPER case, explains:

"We have had a lot of hassles with the controls, mostly when driving it, the part about getting a smooth movement when you drive it so it doesn't go, like, jerk, jerk. If it moves in a jerky way then it will be like, whoops, now it is running, and then you become more nervous about using it. If it just moves slowly in a smooth movement, well then you feel like you have better control over it. And at the same time, it has to be fast but it also has to be safe. We want to be faster than the workmen. Because if not, then they will think, 'then we might as well do it manually, because that's faster.'"

Here, the developers were finally able to truly experience the robot as a technology-in-use, alongside the users. This allowed them to understand the "wobbly" and "tricky" performance that had led to non-use in first testing site. It also allowed the users to learn how the robot developers operate the robot differently from themselves. In the end this process resulted in several adjustments to the robot.

(Based on an interview with Werner, operation and production technologist, robot developer, WIPER)

Both users and developers learn a great deal in the implementation process – which is most prevalent at TRL6+, but feedback from users, with experiences of the robot in their own everyday lives, is important to all design phases and for all robot types. In light of how much post-implementation learning, tinkering, tweaking, and adapting occurs across all REELER cases, the robot developers need help from people, like alignment experts, who knows about the everyday lives of affected stakeholders. They can help anticipate challenges (to situated learning practices), and to successfully integrating the robots on site, rather than assuming a plug-and-play approach. Learning about the technology in use can bring robot developers' imaginaries about use closer to the users' lived reality – which may allow developers to address issues that might otherwise lead to resistance.

So, we studied all these areas and then in the end we had to choose one of them to focus on. I chose interaction design but in the end I wrote my thesis about ethical considerations on the introduction of roads for a construction industry. Yeah, so that's how I ended up here [in Europe] and actually I wrote the thesis with this company. When I was in the third semester of the Master's I discovered that I could do a company period and then I started here full time and I have been here since then for - in three days, it's going to be five years.

(Oswaldo, industrial designer, robot developer, SPECTRUS)

7.3 Education

This section presents findings in REELER's data related to education, specifically on how increased robotization and automation place new demands on education including 1) ethics in engineering education, 2) re-skilling the workforce (who can be reskilled, technological literacy, dyslexia), and 3) the increased need for "learning to learn" in order for workers to remain relevant in an increasingly automated world.

Education: *The social infrastructure and systematization of learning organized knowledge.*

While situated and collaborative learning can address demands on the individual user or organization (e.g. issues in design, such as inclusion/exclusion, education may be an answer to new demands on society, to train the workforce to contend with robotization and to train engineers to incorporate ethical thinking and practices in design processes.

7.3.1 Ethics in engineering education

Oswaldo has a background in computer science from a Latin American country. He studied computer science for four and a half years, and then decided to change to industrial design. He graduated in industrial design and went to a European country to take a Master's degree in IT product design. That is a program with several focus areas, he explains. Among the themes are design anthropology, interaction design, and participatory innovation.

Education to become an engineer is global in so far engineers can work all over the world often involving early contact with companies. There is a close relation between engineering education, companies, and jobs. Sometimes students learn something about ethics, but many of the robot developers interviewed in REELER did not have much experience dealing with ethics in their education (*see 4.0 Ethics Beyond Safety*). Even they are acquinted with ethics in through educaction, once they begin working for a company, discussions of ethics are usually removed from their everyday work. In bigger companies, such discussions are carried out by dedicated branches removed from development.

Samuel, an engineer from SPECTRUS, has a Master of Science in product development and innovation. It is a business-oriented engineering education, with a mix of traditional engineering courses, basic engineering courses, but also management courses and business courses. They are also introduced to ethical issues during this education.

We had some experience-based design courses, where we touched upon ethics. Not a big focus in my education, I would say, but something we definitely discussed. But [in the company] my role was not to focus too much on that. It was more someone like [the social scientist] who was in charge of applying the methodologies that we were using and making sure that ethics is covered in the design process.

(Samuel, product innovation manager, robot developer, SPECTRUS)

7.3.2 Reskilling the workforce

Technological change is not new (e.g. the Spinning Jenny and the Luddites, the automobile, or the computer), but the breadth and pace of technological displacement may be unprecedented. Some caution that this latest technological revolution is different from historical automation events, in that robots and AI may eliminate entire sectors of human labor (Osborne & Frey 2013; Ford 2015). With some automation, not only is a principal activity lost (driving, e.g.), but there is a ripple effect through the supply chains and related markets (e.g., manufacturers of parts, oil and gas industry, parking lots). When workers are not displaced, their work environments, workflows, and requisite expertise are nonetheless changed (*see 6.0 Innovation Economics, 9.0 Economics of Robotization*, and *10.0 Meaningful Work)*. This also goes for the developers themselves, who are regularly offered reskilling courses. Like affected stakeholders, they learn mostly 'in situ' in their own practice.

These changes require reskilling and/or entirely new educations, whether to fit the new demands in an existing job, or to meet the requirements for a new job. Formal education provides the social infrastructure and systematization necessary for a mass reskilling of the population. Still, some simply will not – or cannot – adapt to these changes, and these people may be left behind. It can be people like Karl's Russian worker, a physiotherapist who cannot adapt to the new technologies, or it can be the construction site workers, who love to drill and lay bricks, but cannot get used to operating a robot through a tablet. Across cases, the REELER research find examples of people, who may suffer from technological development if initiatives are not taken to ensure appropriate educational opportunities. As is expressed by this company owner who has begun using brick laying robots:

> *The bricklayer robots, you know them, right? Yeah. They are good for those who know how to, adapt, right? So, there's this thing about being ready to embrace changes. [It is] good for those people who know how to do other things than just laying bricks. But those who don't know how to do anything else than laying bricks, they will somehow end up as the losers in all of this.*
>
> (Jens, CEO at technical equipment rental business, affected stakeholder, WIPER)

7.3.3 Learning to learn

Finally, one of the greatest demands robots and AI are placing on humans is the necessity to constantly stay updated: learning to learn. As work changes rapidly, workers require reskilling to remain relevant in the workforce. Thus, automation is changing the nature of work and the worker. Both robot developers and affected stakeholders feel it is absolutely necessary for the worker to change and adapt in order to stay relevant. In the REELER data, two issues run across cases, and both are tied to education and reskilling of the workforce as robots and AI increasingly change the meaning of the term work. The first issue is the need for continous reskilling and (formal and informal) training, to be able to develop, maintain and operate new technologies. The second issue is how to best educate humans to do, what humans do better than AI and robots - i.e. that which cannot (or should not) be done by robots or AI. Both issues require a flexible work force that learns to learn in a 'meta-perspective'; that is, learning to learn in new contexts rather than domain centered learning. In this respect, the required educational learning is moving beyond situated learning and attempting to create a learning potential across the particular demands in situations (*see Technucation: www.technucation.dk & Hasse 2017* for a further discussion).

Future education is not all about leaning to operate and adapt to robots. REELER's research suggests that our understanding of work is changing altogether as a consequence of robotization (*see 6.0 Innovation Economics, 9.0 Economics of Robotization*, and *10.0 Meaningful Work*).

> *I do not think that safe workplaces exist anymore. You just have to constantly stay updated. Our knowledge and our durability of knowledge changes much faster. Things really change a lot. Especially in the field of programming and technology. If you do not educate yourself and keep up with the times, you will be left behind. So, this working model where you think: 'Okay, I'm at [a very established company] therefore my life is now secured', it will not exist anymore.*
>
> (Marc, university researcher, affected stakeholder, COBOT)

Some, like Marc who is based at a university, recognize that remaining relevant requires a particular way of distinguishing one's labor as something different from machine labor – a craft, or a creative, cognitive job, such as design – while others stress that soft skills will matter most.

I believe that communication is also very important. How do I talk to people? How do I deal with people? Social contact, as it is always postulated, will be more important and not less important as it is postulated, I believe. With these soft skills one can see how someone is dealing with people?! Also, to make a certain reflection and self-assessment.

(Marc, university researcher, affected stakeholder, COBOT)

The questions raised by REELER is who can be reskilled to adapt to and work with robots? Who is responsible for preparing workers for reskilling? And who can decide if it is worth the trouble to reskill a worker? In the future, we may need new educations that aim at determining the best solution in particular cases: AI, robots, or humans? (REELER has proposed the development of a new type of profession *alignment experts, see 13.0 Conclusion*). They could help develop relational responsibility as well as the needed 'learning to learn'. Workers and developers need to remain relevant in an increasingly automated world – and help avoid unnecessary (eventually mothballed) technological developments.

One affected stakeholder, Dan, works with workplace environments in a big construction industry and he tells us about a project with a brick-laying robot, which was supposed to revolutionize construction work.

The robot developed could indeed reduce the workload in some areas, but it increased the work load in others. Where previously a worker had to lay bricks and tiles, the worker now has to feed the bricks and tiles to the robot – and so the problem is relocated.

Then you do that [feed the robot bricks or tiles] full-time and that might wear you down even more than stacking rocks.

(Dan, construction company employee, affected stakeholder, WIPER)

However, even when a robot makes sense, there are some workers who are motivated and willing to use new technologies and others who shy away from them (cf. the Danish Technucation project, see Hasse 2017). But many affected stakeholders, eager or hesitant, will expect or require some help from management or the government, in the form of education or training.

Elif: "I am entirely sure that there are some who won't use it, because they don't dare. So it might be information is very important, and some courses maybe. How can one protect oneself? It is actually very, very important."

Interviewer: "Do you dare to use it?"

Elif: "Well, of course I do! Yes, but, I would rather have the information: How should I use it? What should I do? Instruction is very, very good."

(Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

It may not be all workers who can be reskilled, and even if they can and are willing to, who is responsible for preparing workers for reskilling?

In general, even among the affected stakeholders with the shortest formal education in our REELER research, like the cleaners from Portugal with as little as seven years of schooling, there is a great willingness to learn more:

Interviewer: "Would you like to learn more in this area? The technological part?"

Frida: "Yes, I love everything that has anything to do with science, I like it a lot. For an example this device [audio recorder] is here, it's recording, but how was it made to record? A person is always curious."

(Frida, hotel cleaning staff, affected stakeholder, SPECTRUS)

7.3.4. Reskilling responsibility

However, in order to provide reskilling or a new education for people like Frida, who works as a hotel cleaner in Portugal, it is not only important to recognize that she only had seven years of schooling. Like several of her colleagues, she left school when her daughter was born and is now a single mother. So, it is not enough to provide education – support is needed to help people with practical issues as well.

Interviewer: "Do you think you could reconcile work with [going back to] school?"

Frida: "No, but because I'm living alone. I don't have anyone to help me. I live alone with my daughter and when I'm working she's in school, when I leave work, she leaves the school, then I have to go get her and stay at home with her."

(Frida, hotel cleaning staff, affected stakeholder, SPECTRUS)

Enabling users to observe a robot in use can help learning – but there are differences in how people learn, and (*as argued in 5.0 Inclusive Design*) these differences cannot just be explained away with a reference to age or being 'digital native'.

When I look at my staff, they are very used to taking courses and [adapt to] new things that they have to be aware of and so on. I mean, they're fairly open to the fact that they have to learn new things. Very often we present them with things [and they just say]: 'Ah, now again we're learning something new.' So, for this particular part of the staff, I am actually sure that they are pretty open-minded and also interested. However, when I look at the staff as a whole, I can definitely see some that just can't see themselves doing it, and they will never get around to it.

(Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

However, Inge emphasizes, these difficulties are not about being afraid of or unfamiliar with technology.

Strangely enough, they are all very good at using their smartphone, but if I put them in front of a computer, they kind of freeze. But that might be like 10% of the staff; the rest of them, I'm sure, yes, they would have to work a little bit with the idea. We would have to come up with some really good reasons, why we're doing this, because that's mainly what my staff is, is interested in. Well, if I can present a very good reason, if they can see that reason, they can adapt almost to everything. And then there's a part of the staff, that are gonna love it.

(Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

As Inge is emphasizing here, most people can learn to adapt to new technology if they are given good reasons for doing so in relation to their practice. It is a cross-case finding that affected stakeholders are not always convinced that robots are the best solution – and this may affect their unwillingness to learn to use them. However, from an affected stakeholder point of view, educating the staff to work with robots would in some cases also require a close collaboration with robot developers.

For us, as a team, to go out and convince the staff or teach the staff to use this kind of technology, we have to be very convincing. And you can't do that, if you don't know the product well enough. And the only one, who knows that well enough to be able to also answer all the questions that would arise, would actually be the ones that are manufacturing the thing. So, it would definitely be with the help from whoever is manufacturing the product.

(Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

The robot developers are often aware that new educations are needed.

> *The educational standards need to change, because the tasks, which humans now do, they do not exist anymore. Which means that humans now do higher quality tasks.*
>
> (Nathan, mechatronics engineer, robot developer, COBOT)

However, most robot developers are eager to defend against replacement issues, usually by citing reskilling as a solution. As explained by Arne from the Union previously in this chapter, the CEO robot developers, do not think it is their task to ensure education and reskilling – even if they believe it is needed.

> *So, I mean, it's different. If I am a university person, I have to take care of educating people. Or if I am in a school, I have to take care of educating people. And it's [their] task to explain what a robot is. You cannot ask a company [to do this].*
>
> (Angus, robot developer and CEO, REGAIN)

However, others, like Yves, who is an industrial policymaker, believes it is the companies, who are responsible:

> *We have a social dialogue with employer organizations and basically their tendency is to place the burden of all these changes on the shoulders of the workers; that is they should bear the responsibility for their own employability and they should therefore take on their free time and their salary to pay for their own training. Well, we disagree with that, to be very honest. We actually tend to have the relatively opposite view that it is up to the company to maintain the employability of its workers by paying for the training and by enabling the training to take place during working hours. So you see the positions are pretty different here.*
>
> (Yves, policy advisor, robot maker, COOP)

Some robot developers do agree that companies should take on the responsibility of training workers. But not the companies that *sell* robots, but the companies that *buy* robots. From REELER's data, it's clear that some companies have willingly taken on the task. We have examples of robot developers who work together with the robot buyers to train the staff.

However, even if robot developing companies or companies in general take on this responsibility (at least in the development phases studied across many cases by REELER), they do not take responsibility for people who may be skeptical of technical solutions and question whether robots are the best solutions:

> *We have had robots that were taking over people's tasks. So the way that we try to deal with those users is to try to get them on the train where they become users of the robot. Because in the end, the people who are cleaning now are the ones who have the knowledge of how to clean. And that is very important for the robot to perform in the best possible way. So that is how we deal with the users: we try to teach them as much as possible, we give them that opportunity, and they can grab it or not.*
>
> (Mathias, system integrator, robot maker, SPECTRUS)

This system integrator means that only those willing to adapt to the technology might be retained. This argument shifts the burden of reskilling onto the worker to accept the robot, the same robot that depends on their expertise to function and that will replace them or their colleagues.

If a worker is willing to be reskilled, what kinds of aptitudes and abilities make it possible/impossible? Besides willingness, things like language, cognitive and physical abilities, technical aptitudes, and culture affect a worker's chances of being reskilled. Some manual laborers are not entirely literate, and thus may not have the same aptitudes for acquiring new technical competencies that are based in literacy or academic skills.

> *We also have ethnically Danish people, employees that have very big difficulties reading or writing – we have lot of e-learning programs, and that can be a little difficult for those 30%, I should say maybe more. But that is due to dyslexia? Most of them, all of them I guess, have been to school. I don't think everybody has a level of high school but they, definitely all of them, more or less have levels of junior high.*
>
> (Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

It may be that certain jobs attract people who are less competent or confident in the local language, or who have less education. Many of those working as cleaners in Denmark, for example, were immigrants or descendants of immigrants, and/or Danes who struggled with literacy. In Portugal, most of the cleaners did not study beyond 7-9th grade or fell into cleaning because of some difficult life situations.

> *Yes. That's why I say that I feel embarrassed, because if I had studied, I would have had a better job. I would like to work in a school. I consider all positions. Any [kind of position], because I am not in a position of choosing. I want a proper wage. Yes, and do you know why? Because of the divorce, and my husband leaving for his land, he is going to [a European country] and I remain here with all the bills to pay, understand? I'm very afflicted.*
>
> (Rosi, hotel cleaning staff, affected stakeholder, SPECTRUS)

This points to a significant problem with offering reskilling as the solution to technological displacement – manual labor often includes last-resort jobs appealing to a particularly vulnerable niche of disadvantaged workers (*see 10.0 Meaningful Work*).

7.4 Concluding remarks on Learning in Practice

Learning is a basic embodied process situated in material and social environments. Through these processes we gradually build situated knowledge of these social and material environments – which may be disrupted, when something new comes into our lives. Robots and AI can be seen as such new phenomena which come into people's everyday lives and challenge their habituated learning habits and their situated knowledge of how things are and should be done (and even, as noted by Lave and Wenger (1991) their identities). If workers are unfamiliar with the new technologies entering their workplaces – or are only acquinted with them through popular media, technological changes may be met with fear and skepticism. When people learn what robots really are, part of this fear is often alleviated; or, fear of the unknown is replaced with a more grounded and realistic skepticism. In any case, whenever a robot is implemented in a practice, a learning process is initiated, whether connected to an explicit training or not. Robots can be more or less intuitive, but situated learning will always be an issue when new technologies are implemented. To create 'intuitive robots', the robot developers need to learn from users what matters to them, and they need to be aware that not all users share their sense of what is intuitive, when it comes to operating a robot. Though it is a difficult task, there is a lot to be gained from following technology-in-use in an everyday practice, and not just in laboratories.

However, formal education is also needed in at least two ways: 1) To operate, maintain and co-exist with robots in everyday work life. 2) To establish a learning-to-learn paradigm, which facilitates workers' developement of new skills, to compensate for those tasks taken over by robots. Here, there is a basic dilemma. It is not clear who will feel ethically responsible to reskill a workforce in response to robotization. Across cases in REELER, many robot developers, especially from big companies, see it as part of the robot development to offer re-skilling of workers, however other robot developers are unwilling to do so. Generally, the upskilling and education of workers made redundant by robots and AI remain largely an unsolved problem – and it is further complicated by the fact that we do not know what kinds of educations will be needed. What REELER research point to is that it is not just a question of reskilling 'digital natives' who are able and willing to engage with robots. For many stakeholders, going back to school is not possible (for financial or social reasons) without societal support – even when they are willing to learn. Furthermore, REELER findings indicate that we also need to be careful in determining, in which cases robots are preferable to humans and vice versa. Finally, we need to prepare our educational system for the possibility of a robotic future.

Concluding remarks to Part Two

As noted in the introduction, one of REELER's main recommendations is to apply a two-pronged strategy to improve responsible and ethical learning in robotics. We have shown that robot developers, mainly engineers, have much to gain from learning from end-users and affected stakeholders. This awareness may pave the way for more ethical and responsible learning in robotics and may even lead to new and more productive innovation processes. Yet, we have also found many issues that are so complicated and tied into wider societal concerns that it would be unreasonable to ask engineers and other robot developers to solve them all.

In this first part, we have mainly focused on issues tied to the original objective of the REELER project; namely to align robot developers' (and especially engineers) visions of a future with robots with empirically-based knowledge of their own understandings, while providing new insights into the REELER findings on situated practices and innovation models. By giving voice to those affected by robots, we envision not only more ethical and responsible robots, but also a potentially better uptake on robots, simply because the robot developer's iterative design practices can be improved. To that end we have developed a number of tools that can be found online (*see www.responsiblerobots.eu*) aiming at helping robot developers improve their practices.

In this section (Part Two), we have mainly focused on enhancing robot developer's awareness of how they view ethics, humans and how design can be hampered by their own normative perceptions of affected stakeholders, their needs and concerns (*4.0 Ethics Beyond Safety and 5.0 Inclusive Design*). We have also pointed to the enormous complexity and uncertainties in engineering design processes – and the need for iterative processes that consider both structural aspects and situated practices (*6.0 Innovation Economics and 7.0 Learning in Practice*).

Already from reading this section, it is clear that the burden of ensuring responsible and ethical learning in robotics cannot be put solely on the robot developers, nor the application experts helping them to develop robots. Not even the facilitators (the third sub-group of robot makers) who fund and make policy concerning robots can be expected to solve these problems on their own.

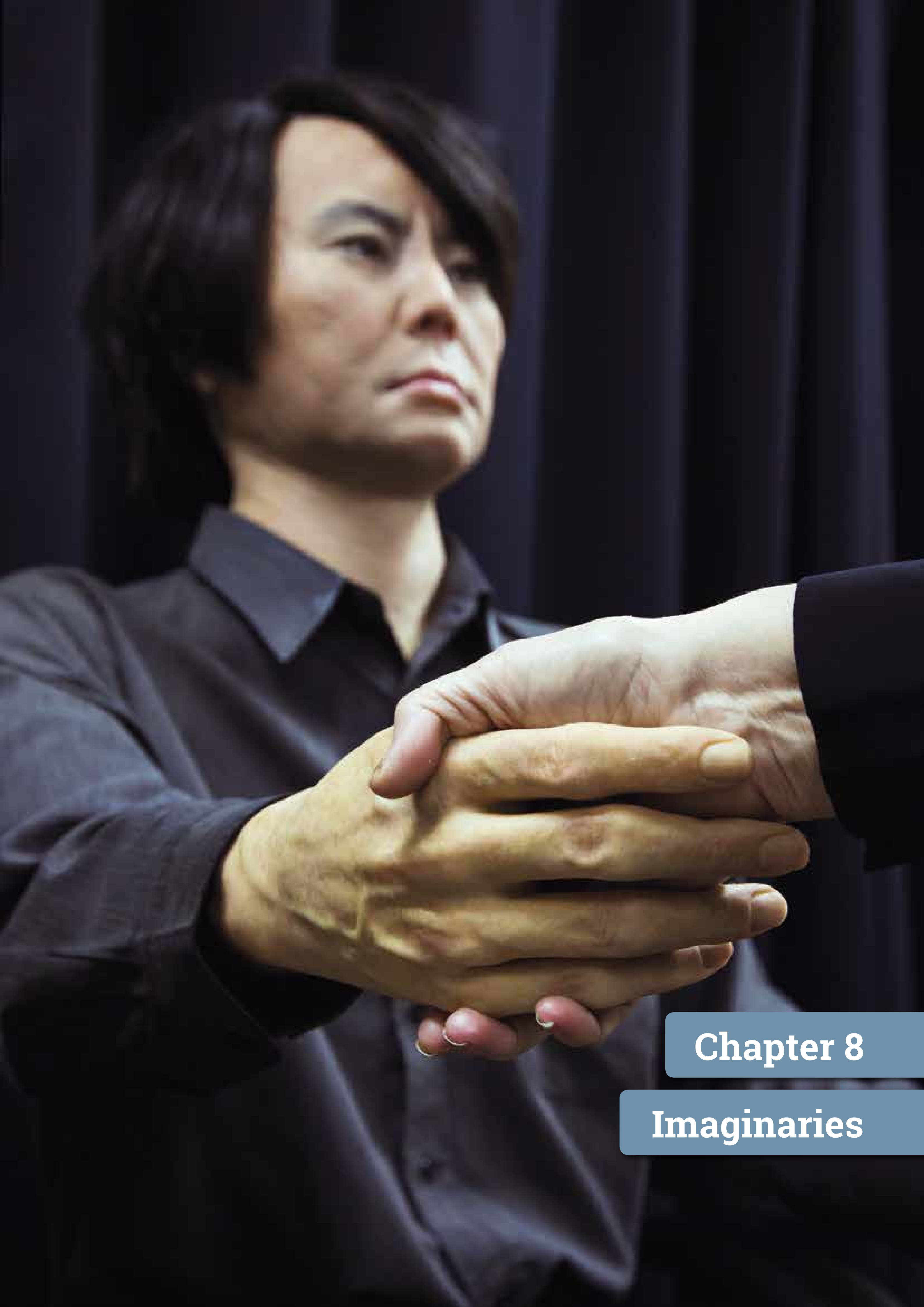
In the last part, Part Three, we unfold the wider context of the challenges we can envision in a society permeated by AI and robotics. We argue that relational responsibility is one step towards solving these problems. We end Part Three by explaining what we see as a need for a new profession of *alignment experts*.

PART THREE
Expanding beyond the inner circle

In this part of Perspectives on Robots, we present REELER discussions tied to the wider societal issues found in our research. Though these issues may still be relevant for the robot developers, as well as the design processes involving the end-users and directly affected stakeholders discussed in Part One and Two, we move into issues of wider societal importance in the subsequent chapters.

We look at the wider issues to be dealt with by robot makers responsible for legislation and funding and societal developments (including a gender perspective). We also look at how our perceptions of robots differ from hands-on experiences and how this creates a gap between those who only know robots from media presentations and those who encounter robots in their everyday lives. We scrutinize how robots may influence distantly affected stakeholders through the robotization of society – and how this development may influence a meaningful work life.

Finally, we present the Human Proximity Model and our two-pronged strategy as a way to not only address the design processes but also how to deal with the wider societal implications of robots with the aid of a new profession we name alignment experts.



Chapter 8

Imaginaries

Child 1: I don’t like robots too much because I have a theory that robots will conquer people.

Interviewer: Will they?

Child 2: It is going to be a rebellion.

Interviewer: Do you think that’s possible?

Child 2: Yes.

(Children interviewed about robots, affected stakeholders, ATOM)

◀ Robot imaginaries may spin out of control, when they lose their moorings in materiality.
(Photo by Kate Davis; featuring Geminoid™ HI-2: ATR Hiroshi Ishiguro Laboratories)

8. Imaginaries

Roomba vs. Terminator

You will find here

- An introduction to the concept of imaginaries and examples from public discourse
- Empirical examples of the component part of imaginaries about robots
- Various definitions of a robot
- The role of media

You will acquire

- Awareness of how imaginaries are formed
- Awareness of the role of media and advertising in forming imaginaries
- Awareness that no one definition of a robot exists
- Awareness of how imaginaries influence perceptions of robots

8.1 Introduction

Humanoid: *Entities that are human-like in appearance. E.g. bipedal, stereoscopic vision, opposable thumbs.*

The concept of 'robot' exists in a precarious intersection of public policy, cultural representation, technological innovation, capitalism and philosophy. Yet, no singular definition or understanding of what a robot *is* exists. The same term is used to discuss entities potentially worthy of rights and responsibilities, automatic vacuum cleaners bumping into furniture, or classes of entities ranging from humanoid robot-partners to industrial robot arms. Consequently, the concept may be seen as a moving target, imbued with both interpretations of the current state-of-the-art and visions about the futures.

In this chapter, we present the concept of *imaginary* to help make sense of the debate about the nature of robots, understood as both a concrete materiality and an abstract concept, as it emerges in the REELER data and in public discourse. We argue that robot imaginaries spin out of control, when they lose their moorings in materiality. This we illustrate by comparing robot imaginaries in the public discourse with the robot imaginaries REELER identify among the robot makers, who are well-grounded in the practical work of engineering and thus have a more informed conception of what robots are and can do. We investigate the role of popular media and corporate advertising in shaping robot imaginaries among stakeholders, policymakers, and robot makers, in order to further underline this point.

8.2 What is an imaginary?

The concept of imaginary has a long and varied history, and has been defined in many different ways by different people (e.g. Anderson 1983; Castoriadis 1975; Lacan 1949). In particular, the concept has garnered significant interest within the field of Science and Technology Studies (STS), and has spawned myriads of types of imaginaries (see McNeil 2017 for an overview). In this section, we present some characteristics of an imaginary, without endorsing any particular definition of it.

Briefly, the concept of imaginary comprises *an interpretation* of the present connected with a vision of the future. Following philosopher Kathleen Lennon, we might characterize the first element of the concept as "the affectively laden patterns/ images/forms by means of which we experience the world, other people and ourselves" (Lennon 2015, 1). Some of these patterns are historically rooted. For instance, in Japan, some argue that robots are generally conceived of as positive, because the Japanese view robots through the lens of history. This is because the development of robots played a crucial part in the development of the Japanese post-World War II economy, which made Japan one of the biggest economies in the world. In the western world, automation was rolled out under the aegis of Ford and Taylor, which, together with cultural forces, carved out an image of automation in the West as something hostile to human interests (Robertson 2014).

These different cultural interpretations of the fictional robot are reflected in the science fiction writing of the time. American writer Isaac Asimov and Japanese manga artist Tezuka Osamu each crafted laws of robotics governing human-robot interaction long before the technologies were developed to make such interactions possible. "Tezuka and Asimov were socialized in cultural settings differently shaped by World War II and its aftermath, a fact reflected in how they imagined and described the relationship between humans and robots in their literary work" (Robertson 2014, 583). Asimov's laws drew on the threat of a Frankenstein scenario in which the robots turn against their creator, as in Čapek's *R.U.R.* In contrast, Tezuka's addressed "the integration of robots into human (and specifically Japanese) society where they share familial bonds of kinship and perform familial roles" (Robertson 2014, 584). Returning to Robertson's writings *Robot Rights*, the ways in which robots are interpreted and regarded in Japan – in contrast to their reception in Europe and the U.S. – demonstrate how media representations reflect and reproduce our cultural imaginaries. These cultural imaginaries can influence robot makers' notions of robots and their reproductions of notions of the human through robotics (Suchman 2007). It can also affect the affected stakeholders' view of robots, thus making it more difficult for robot developers to get their work accepted. In fact, some robot developers pointed to this very dichotomy when addressing public imaginaries of robots:

> *In every Western movie, the robots are the ones that destroy humanity. In looking at Asian movies, robots are the ones that save humanity. So, it starts from the beginning, childhood comic, that robots are the good and not the bad guys. Yes, we say here [in Europe] that we have neither the technology nor the acceptance.*
>
> (Kai, mechanical engineer and cluster leader, robot developer, COBOT)

These representations and imaginaries can shape our interactions with robots (Suchman 2007), our regulation of robots (Robertson 2014), and the creation of our common life-worlds (Hasse 2015). As we shall see later, the representations of robots within popular media have informed robot imaginaries, preferentially among stakeholders, but also among robot makers.

The other element in the concept of an imaginary consists of a vision of the future. We can think of future societies, where the immense wealth generated by automating large sections of the economy leads to a truly affluent society, where no one wants for anything. The opposite vision also exists; a small elite reaps most of the rewards, while the majority of people can barely scrape by. Depending on our vision of the future, we have, in the present, a way of interpreting the world. Adherents of a positive view of the future might interpret increasing automation as a good thing, since this brings humanity closer to the desired future, and vice versa.

In some classical accounts of the imaginary, e.g. Castoriadis who characterized imaginaries as 'the curvature to every social space' (op.cit. Castoriadis 1987, 143; Strauss 2006, 339), imaginaries are conceptual superstructures shared by an entire social group; for instance, African-Americans in the 1960ies. Like Claudia Strauss, we reject this notion and focus instead on the imaginary as something personal, since ultimately imaginaries can only work, if they are people's imaginaries (Strauss 2006). However, this does not suggest that imaginaries cannot be shared among people, such as among practitioners within a certain field. For instance, Borgmann (2006) refers to an engineering culture. Since the field of robotics includes both the craft of creating robots (the practices) and the robot developers, who are the human engineers, IT-experts, etc. conducting this work (the practitioners), these engaged engineering experts form what Jean Lave and Etienne Wenger (1991) called a 'community of practice', constructing certain understandings through their shared activities. Indeed, robot developers seem to share a more pragmatic approach to robots than the general audience, seeing them as less humanlike and more like pieces of machinery. Yet, as we shall see, there is not one single shared robot imaginary, but rather a patchwork of different elements that make up quite different imaginaries – however, with a weight on robots as material objects. Some are closely linked to AI and machine learning, others to the importance of machines 'doing good' and avoiding harm. For this reason, we find it more productive to discuss a shared **imagination horizon**, a collectively available cultural pool of conceptual resources. One example might be definitions of robots or specific visions of the future, which individuals draw from in forming their imaginaries. Forming an imaginary is not a conscious process of evaluating and picking out the elements most appealing to any particular individual. Rather, it stresses that the horizon can be thought of as a multi-dimensional Rubin's vase, where there are limits to what can be seen even when different individuals see different things.

Imagination horizon: *A collectively available pool of conceptual resources, from which individuals draw out the elements constitutive of a given imaginary.*

To give an example of how all of this comes together, and how clashes between different imaginaries come about, consider the case of military robots. Supporters argue for utilizing autonomous weapon systems in war on the ground of these being superior to humans in precision, efficiency, ability to

The Wizard-of-Oz effect reproduces robot imaginaries inconsistent with robot materialities. (Photos by Kate Davis; featuring Geminoid™ HI-2: ATR Hiroshi Ishiguro Laboratories and Telenoid™: Osaka University and ATR Hiroshi Ishiguro Laboratories) discriminate combatants from non-combatants, and the absence of psychological stressors. As Ronald Arkin of Georgia Institute of Technology puts it:

"Unfortunately, humanity has a rather dismal record in ethical behavior on the battlefield. Potential explanations for the persistence of war crimes include: high friendly losses leading to a tendency to seek revenge … dehumanization of the enemy ... pleasure from power or killing or an overwhelming sense of frustration. There is clear room for improvement and autonomous systems may help address some of these problems." (Arkin 2013, 5)

Critics have not denied these potential benefits, but instead they focus on the ethical implications of building robots capable of making decisions about life and death. Some fear an international arms race, and an increased willingness to go to war, since warring countries would 'only' be risking robots – not humans (Russell et al. 2015). Fundamental to this line of argumentation is that robots (and AI) should benefit humanity. As one robot maker puts it in a REELER interview:

> *We don't want the robots to be soldiers, we want the robots to be service robots, helpers.*
>
> (Salome, communications director at a robotics company, robot maker, BUDDY)

What is at stake here is a fundamental split in the imaginaries of the robot. For supporters of autonomous weapons systems, there is a clear-cut argument for using robots in war; they are simply more effective at realizing the goals of warfare. For opponents, using robots for warfare is, however, unethical.

8.3 What is a robot?

In the course of collecting our data material (*see Annex 4*),[1] we found that no single definition of robot was dominant among neither robot makers nor stakeholders. In fact, many robot developers, when asked about a definition of robots, explicitly stated there is no dominant definition of robots.

> *I have absolutely no idea what a robot is.*
>
> (Edgar, system architect, robot developer, SPECTRUS)

1 see responsiblerobotics.eu/annex-4

This finding is consistent with the literature, where several different definitions exist side by side. Some are concerned only with the mechanical configuration of materials; others add conceptual and functional properties also. Not surprisingly, Institute of Electrical and Electronics Engineers (IEEE) stated:

"The term robot may have as many definitions as there are people writing about the subject. This inherent ambiguity in the term might be an issue when specifying an ontology for a broad community. We, however, acknowledge this ambiguity as an intrinsic feature of the domain." (IEEE 2014, 4)

The International Organization for Standardization (ISO) and IEEE offer the following definitions of robots:

"A robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention." [2]

"Robot: An agentive device in a broad sense, purposed to act in the physical world in order to accomplish one or more tasks. In some cases, the actions of a robot might be subordinated to actions of other agents, such as software agents (bots) or humans. A robot is composed of suitable mechanical and electronic parts." (IEEE 2015, 5)

These definitions center on a common theme, which we label *materiality and processes*. Here we discuss **robot as materiality**. However, in our data, another perspective consistently turns up in the robot makers' characterizations of what a robot is. This other theme we call *concept and function*. Here we discuss **robot as concept**.

> **Robot as materiality:** *A theme relating narrowly to the technical aspect of a robot, i.e. which material properties (if any) must be present, and which processes much be instantiated for an entity to be a robot.*

> **Robot as concept:** *A theme grouping together phrases that pertain to the conceptual side of a robot.*

To differentiate the two themes, we highlight the sort of questions dealt with under each of these themes. In the following, we briefly characterize the two themes and move on to, firstly, present our main findings in regards to materiality and processes, and secondly in regard to concept and function.

Materiality refers narrowly to the technical aspect of robots, and deals with questions such as: Some make a distinction between a robot as physical (like an automatic vehicle), and robot as pure software (as artificial intelligence (AI) built into

2 ISO-Standard 8373:2012 Robots & robotic devices: https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-2:v1:en

robots). However, even software is in the end composed of materials. So, the question rather becomes what sort of material processes characterize a robot?

It is useful to, and robot makers often do, frame this pair (materiality and processes) in terms of hardware and software. As we shall see, thinking about software and hardware as being opposite ends of the same spectrum helps map robot makers' differing attitudes about what constitutes a robot.

Concept and function, on the other hand, deal with higher-order questions, which are, in principal, less tied to current technical development. We stress the principal nature of this feature, because in practice most of the interviewed robot makers have their answers thoroughly grounded in the current state of robotics as machines. In theoretical terms, the pool of cultural resources available to robot makers, i.e. their imagination horizon, contains a sophisticated, practice-based vocabulary for discussing robots in terms of technological components (e.g. actuators, servo-motors, and sensors). They often contrast this with the more widely shared cultural representations of robots, such as those of Hollywood movies and science fiction literature. Questions that fall within the theme of concept and function are: What is the purpose of robots in society? Are there certain roles, which robots should never fill? What will robots be like in the future?

Our findings within this theme ties in with the robot developers' understanding of themselves as working for the benefit of society at large, having a genuine interest in doing good (*see 4.0 Ethics Beyond Safety*).

8.3.1 Materiality and processes

We frame our findings under the theme of materiality and processes by invoking the previously mentioned spectrum, with hardware and software occupying the extreme ends. Put differently, someone might suggest robots are primarily characterized as a particular configuration of materials and less so, or not at all, by the (equally material) program being run on the platform. In the REELER data, the vast majority of robot makers agree that robots must be physical things, tangible in the everyday day life. They also agree that this is not sufficient, and most of them are adamant that both materiality and software process are required:

> *It has software, it has mechanics and it has hardware. And it can't work without any of those (…). Pure robotics people in the university will understand robotics as just software, but in the real world you need all of them, and you cannot work without the other.*
>
> (Edgar, system architect, robot developer, SPECTRUS)

As artificial intelligence is increasingly built into the carcass of robots, some robot makers become willing to see robots in the future as pure software. The vast majority of robot makers are somewhere in between the two extremes; conceiving robots as either a material thing animated by software, or as the physical instantiations of the software. Here, we find the mentions of artificial intelligence (AI) and often machine learning (ML) as part of what constitutes a robot.[3] The connection between robots and AI helps provide the physical anchoring of some hybrid imaginaries, which blend fears about future AI systems taking over the world with ideas about robots (Bostrom 2012). This also leads some robot developers to suspect that definitions of robots will put more emphasis on software in the future, given that the development of AI (ML in particular) seems to be racing ahead and about to have a more substantial impact on the field of robotics. We shall return to this point in 8.3.2.

A clear trend in the data is that a robot is an entity, which carries out three connected processes: (i) sensing the environment, (ii) analyzing/processing the sensorial data, and (iii) acting on the environment based on that information:

> *To me a robot is a device that sort of senses something and then it processes that data, and then it takes some kind of decision based on that. It's sort of an autonomous decision in a way that some of it is, of course, based on algorithms and so on, some of it could be based on AI or more intelligent ways of doing it. But it's something that senses, processes the data and then it does something that reacts.*
>
> (Samuel, product innovation manager, robot maker, SPECTRUS)

This triad of sensing, processing and reacting is often coupled with adjectives such as 'predictable' and 'reliant', meaning that given a specific input, you would be sure to get a certain output.

The characteristics listed above are, in fact, true of many machines that are typically not associated with robots; a dishwasher, for instance. Some robot makers are happy to concede this point, others less so as they would demand the robot exhibits some form of intelligent behavior. In brief, on the theme of materiality and processes, we find that although no dominant definition of robots exists, there seems to be

3 Machine Learning (ML), understood as learning systems, which are not explicitly programmed, is a sub-category of the field of artificial intelligence (AI). Often ML is contrasted with symbolic or Good Old-fashioned AI (GOFAI) (Haugeland 1985), which is based on explicit programming, i.e. systems encoded with rules, often stated in terms of if X then Y. See Russell & Norvig 2009.

consensus among robot makers that a robot is characterized by physical entities comprised of a suitable mixture of hardware and software, which process data following roughly the schema of input-process-output in a reliable way.

8.3.2 Concept and function

Our findings on the theme of concept and function revolve around three main adjectives and one noun used to describe the functioning of robots. We asked most of our interviewees, both affected stakeholders and robot makers, to name five words they associate with the term *robot*.[4] The three words presented below are the more frequent responses, in order of significance and rate of occurrence.

1. Autonomous.
2. Helpful.
3. Intelligent.

Most robot makers describe robots as having some amount of autonomy, and many describe robots as being helpful or supportive of humans, while some robot makers describe robots as intelligent, although they rarely specify what they mean by intelligence.[5]

One noun is used across our cases to describe robots: machine. Yet, machine is used in at least two different ways to evoke different connotations, as is exemplified in the two following quotations:

> *The problem is not the physical robot, the problem is the mind of the robot, because I think the intelligence of the machines is growing and it's growing very fast. I think, now it [the robot] is more intelligent than the humans.*
>
> (Hugo, mechanical engineer, robot developer, HERBIE)

> *So, it [the robot] is a device, it's a different way of interaction, if you compare to a screen, but it's always a device. I have no imaginary of robots as something different than a machine.*
>
> (Alba, robot developer, REGAIN)

4 See Annex 1 (responsiblerobotics.eu/annex-1) for a discussion of how interviewers followed our interview guide.

5 Just as for the term robot there is no universally accepted definition of intelligence in the literature. For an overview see Legg & Hutter 2009.

Robot makers thinking about robots as *"just a machine"* (Monika, scenario developer at robotics start-up, robot maker, ATOM) play on the connotations brought out by the definition of machine:

1) An assemblage of parts that transmit forces, motion, and energy one to another in a predetermined manner.
2) An instrument (such as a lever) designed to transmit or modify the application of power, force, or motion.[6]

In the literature (e.g. Nevejans 2016), some scholars have played on the same connotations. Nathalie Nevejans is an appointed expert on law and ethics in robotics by the European Commission, and in her discussion of the 'European civil law rules in robotics', she presents the robot as a lifeless material artefact when providing definitions like, "a mere machine, a carcass devoid of consciousness, feelings, thoughts or its own will … just a tool … inert … inhuman … non-living, non-conscious entity" (ibid., 15-16). Using the word *machine* in this way is often coupled with framing robots as tools. In this sense, it would be wrong to make:

> *The person think that the robot is his friend, and it will help him in anything. It's just a robot, it's a tool you can use or you cannot. You cannot confuse [trick] that person to think that it [the robot] is going to be a friend.*
>
> (Nima, robot designer, robot developer, BUDDY)

Building such a robot would, from this perspective, mean creating an illusion of the robot being something more than it is, namely an entity capable of forming real relations with people. We will return to this discussion in the following section.

In the quotation by Hugo in the beginning of this section, we find the word *machine* used as a descriptor, which might apply to any mechanical system. It also serves as a neutral contrast to the materiality of robots and humans; robots are made of different arrangements of atoms than humans, but might be no different in principle. This stream of thought also exists in the literature, as for instance in the title of the now seminal work by Boden (Boden 2006, *Mind as machine: A history of cognitive science.*). Such discussions are also widespread in the academic literature on ethics with an entire subfield, machine ethics, dedicated to the possibility of machines being moral agents (Sullins 2011). However, in none of the REELER cases did we see any robots displaying anything close to 'humanlike' intelligence. Apart from the appearances of the humanoid robots we saw (in e.g. BUDDY and ATOM), the robots

6 From the Merriam Webster Dictionary. Retrieved from https://www.merriam-webster.com/dictionary/machine

looked like machines – and even the humanoid turned out to run on the same types of materials as the machinelike robots.

In the list of associations to the word *robot* among REELER robot makers, *autonomous* was the most frequent. It is important to note that autonomy, in the technical sense, differs somewhat in meaning compared to the way it is used in common parlance and, often, in the philosophical literature on the subject. The word can be translated as self-ruling, and is usually used in this sense, often connected with the notion of free will, when discussed in relation to individuals. However, in the field of robotics, it usually describes systems operating without direct human control. As one robot developer points out:

> *It can do things on its own but anything it does has been pre-programmed by humans.*
>
> (Theo, university researcher, robot developer, SANDY)

This statement is completely in line with what was found across all cases by REELER researchers. All robots had, at some point, to be programmed by humans. It is in this limited sense that the word autonomy mostly shows up in our data, which means autonomy in the traditional (philosophical) sense is very limited with robots at the present state of technological development:

> *These are of course interesting visions, when they [the robots] walk around completely autonomously. They are probably also programmed in the films. They learn everything by themselves. We are very far from this. Here, I have to program every single pose.*
>
> (Alexander, development engineer, robot developer, COBOT)

Autonomous robots are thus understood as robots able to operate without the direct intervention of humans like C3PO in the Star Wars movies. Some robot makers go further and make the strong claim that robots will never be able to progress beyond the present day 'primitive' form of autonomy (and never be able to move like C3PO). Because they are the product of human programming, they will never do anything else than what we program them to:

> *It's impossible, it's completely impossible. Robots will never say: 'I am a robot working in a warehouse, now I'm going to the moon. Yes, that is a good idea, hmm, that's cool.' Never, impossible. It's because they don't understand the nature of programming, programming is just programming.*
>
> (Alph, robotics start-up founder & CEO, robot developer, WAREHOUSE)

In our data, we also find that the robot makers, who claim the opposite, namely that robots can at some point move beyond this form of autonomy, usually connect this with an increase in intelligence. However, as we shall see, the use of the word intelligence also varies among the robot makers. While many use the word *intelligent* to describe robots, they do not ascribe the same semantical meaning to it. For some, the word intelligent is connected to autonomy.

> *The word intelligent is perhaps a bit tricky, but automation and intelligence will probably be attached to it in some way, it can carry out some tasks on its own, right?*
>
> (Elias, university researcher, robot developer, WIPER)

For others, intelligence is synonymous with the ability to do more things, or do the same thing more efficiently. Both things suggest that robot makers operate with a narrow concept of what constitutes intelligence. For the same reason, a calculator can be said to be intelligent, in that it is a very efficient way of computing certain types of mathematical problems. This conception of intelligence is mirrored in the discussions of AI, where 'narrow' or 'domain-specific' AI is often contrasted with general AI (Nilsson 2009). We typically think of intelligence in a general sense, as something going across multiple domains. We even label individuals, who lack general intelligence, but possess highly evolved single-domain intelligence as 'savants', which might be a fitting label for some advanced robots that do well within one particular area, but are unable to generalize this proficiency to other areas.

For a third group of interlocutors, the word intelligence suggests something deeper than just behavior. In recent years, machine learning (ML) systems have progressed to a state, where they can display behavior, which, if a human had exhibited the same behavior, would be considered intelligent by some. For instance, using ML systems, it is possible to turn pictures into paintings in the style of Picasso, Monet or other famous painters. But as one robot maker puts it:

> *It's like this, these neural networks that learn how to paint like van Gogh. Surprisingly, the machines are capable of, you know, in a way, making an internal map of what's his style and then you show a picture and they paint; it's really impressive. So how does it work? We don't know. And does it require any understanding of who van Gogh was or anything? No."*
>
> (Edgar, system architect, robot developer, SPECTRUS)

As another robot maker argues, this is not the genuine article, but merely a simulacrum, even if it is called intelligence:

> *You probably know one person with big memory and another person with no big memory, but [that person] is more intelligent, because [he] can solve one problem without previous knowledge about this problem. This is real intelligence. Computers don't have intelligence, only calculus. And the calculus today, the sciences say it's intelligence.*
>
> (Sebastian, CEO, robot maker, HERBIE)

Finally, when we asked the robot makers to name five words associated with robot, many of them mentioned the word *helpful* (or *help* or *helper*). This supports and connects with another finding on ethics that robot makers genuinely want to do good, i.e. make the best possible robots (*see 4.0 Ethics Beyond Safety*). Many robot developers think seriously about how and where robots should be implemented to realize the goal of them doing good with robots as helpers, although it often boils down to being safe and efficient and not being harmful. However, some robot developers see robots as a transformative force, and acknowledge that it has the potential to do both great harm and great good, depending on who is using it.

Other of our interviewees argue that both the robot itself and its use are salient factors in determining the value (often in the moral sense) of a robot. If we follow this line of reasoning, it suggests that the label helpful is subject to this same form of relativity; whether or not a robot is helpful depends partly on the robot itself, but also on where and how it is being used. 'Help' like 'relief' (*see Meaningful Work, section 10.3*) are relational terms, and what we mean by them needs to be aligned (*see also 12.0 Human Proximity*). Like with the word intelligence, we find that few robot makers are explicit about what it precisely means for robots to be helpful. Take for instance the guidelines for safety, which apply to all robots. Often, robot makers will say that robots have to be safe, and they have explicit notions of what safety means in concrete situations (*see 4.0 Ethics Beyond Safety*). This is not the case, when they say robots should be helpful. Here they lack explicit notions of how a robot is helpful. Furthermore, one of our findings in *5.0 Inclusive Design* is that robot makers can fail to take affected stakeholders' lifeworlds into account when designing robots. In the same fashion, it stands to reason that robot makers can fail to grasp what affected stakeholders experience as being truly helpful – and also overlook potential resistance to the help they offer.

8.4 The role of media and robot makers

In the last few years, the presence of robots in the public media has increased immensely. Robots now often appear in movies, literature, on social media, and in the news. This also influences the concept of robots to a high degree. Yet, even with robotic technology said to influence every aspect of living by 2020 (euRobotics aisbl, 2013), most people are still not exposed to robots [7] in their everyday lives. Thus, most people rely on media, in the broad sense, for information about robots. However, according to many robot makers, the information found in public media tends to paint a false picture of the current state of robotics.

In this section, we present our findings on how robot makers perceive the link between media representation of robots and public imaginaries of robots. In particular, we see that while robot makers are right in pointing out the problems of exaggerated media depictions of current robot capabilities, they sometimes contribute to this exaggeration themselves in the way they present their robots – to attract funding or potential buyers. As a consequence, the gap between robot makers' often technically grounded imaginaries of robots and public imaginaries of robots widens.

When we look at the criticism that robot makers levy at media portrayal of robots, we see two different types pertaining to (i) materiality and (ii) concept. The first type of criticism is technical, and it aims at the media portraying robots as more capable than they are, for instance by portraying robots as better at handling the sort of tasks, robot makers try to have them handle. One robot maker puts it:

7 Here, and in the euRobotics report, the term robot excludes what is typically referred to as appliances, even though they fit some robot definitions (see sec. 3)

Science fiction has a role in how robots are conceptualized and represented – as seen in a robotics laboratory. (Photo by Kate Davis)

The robot is there to do this and that. Or the robot will do this and that easily in the future. But we are around 20 years from these results. So, the picture [presented by the media] is just simply too far ahead. I have done some interviews and most of the time – thank God – they sent it beforehand, but sometimes not. And then they write such bullshit, which I first of all didn't say that way and second of all, which is simply not true. Well, that is because the press is not very mindful when it comes to technical things. No one checks it and then they just publish it.

(Nathan, mechatronics engineer, robot developer, COBOT)

According to robot makers, such representations cause fear in the public, leading to increased antipathy towards robots, because people are afraid, they will lose their jobs or robots will harm them. Robot makers point out that such fears are often alleviated by exposure to 'real' robots, which helps reset expectations about what robots are able to do. In the REELER data, we find evidence to support this claim. In *Learning in Practice, section 7.2.1.*, we introduce Elif, who is initially fearful robots will destroy everything, but who, upon being shown a video of a real robot by an ethnographer, exclaims that she likes it and think it's a good idea.

Overly positive representations not only evoke fears among affected stakeholders, they also excite robot buyers, who are not technically trained or knowledgeable about robotics, and come to robotics with too high expectations about what robots can do:

I will name a typical, hm, who could we take, maybe like retail companies are coming and saying: 'We need a robot to stock up the shelves in our store, I have seen all that on YouTube, the robot reaches out, picks it up, puts it down and it can't be that hard.' So, that means with customers who are not in contact with robotics, their expectations to robotics are extremely high. Probably due to a certain public, yes, everyone shows how great they are, especially the publicly funded projects show off what they have done.

(Kai, mechanical engineer and cluster leader, robot developer, COBOT)

As indicated, this can actually lead to problems for the robotics companies themselves. Customers and stakeholders' high expectations sets them up to be easily disappointed when confronted with real life robots. This can prove to be a problem for implementation in the workplace, as one robot developer points out:

When the robot doesn't demonstrate that level of intelligence and does something which indicates it has a lack of intelligence, like it's facing a wall and it's talking to the wall or something like that, then people have a kind of negative reaction to it. And kind of dismiss it as something useful because it doesn't meet that certain expectation of where they think robots should be.

(Paul, head of social robotics lab, robot developer, BUDDY)

Nevertheless, robot companies themselves engage in this sort of representation of robots. Across our case studies we find robot makers promoting their robots in ways that represent their robots as more advanced than they currently are. In this way, robot makers inevitably contribute to the same tendency they criticize in media.

Not that smooth. Not that functional. I mean, it [the robot in a promotion movie] moved quite in a smooth way, knowing exactly the direction, knowing exactly where the human was. But in the real life, it's not like that [laughter], we all know. And of course, it would require a lot of more inputs.

(Arturo, engineer, robot developer, REGAIN)

We realize that robot makers are just playing by the rules of regular advertising, as they themselves point out, this is simply what sells:

Because it's what people like. When you have an advertisement for a car, why is there always a nice girl driving it? Same thing.

(Alba, robot developer, REGAIN)

Moreover, some engineers involved in the technical aspects of the robot (who we refer to as robot developers) are typically not part of the process of advertising and selling the robot, and in that sense, they are not to blame for the unrealistic portrayal of robots. However, the presentation of 'more capable' robots and the use of media people as application experts 'overselling' robots seem to be part of an inherent business model found in a majority of REELER cases.

As pointed out in the beginning of the chapter, the general public – affected stakeholders – is far less exposed to robots compared than to, say, refrigerators. Consequently, representations of robots that are not grounded in technical realities help reinforce public imaginaries of robots as more advanced than they currently are, and thereby produce the same imaginaries that robot makers criticize.

The second type of criticism is aimed at popular media, often in the science fiction genre, and the portraying of robots as having fundamentally new qualities, which they do not have at present and might never have, such as full autonomy, (human-like) intelligence and emotions.

> *Their expectations are influenced obviously by science-fiction and what they read or see on the screen. And so, when they see a robot in real life, particularly if it's the first time, they expect it to be just like a robot out of Star Wars or something like that.*
>
> (Paul, head of social robotics lab, robot developer, BUDDY)

Dominik Boesl, formerly of KUKA robotics, has been a staunch voice on this topic, and in a talk at the European Robotics Forum in 2017, Boesl said:

"Last year there were eleven movies in Hollywood that were talking about robotics and AI. And it starts cuddly and nice at Baymax or Hero Number Six, I think it's called in the US. So, a Baymax movie, a Disney movie. Then you have Avengers, Age of Ultron – nice cool action movies. Up to Her and Ex Machina. But eleven movies put robotics and AI and science fiction, for example in this form, in the heads of people. So, this leads, on the one hand, to a completely distorted view on the state of technology today. People believe this is going to be real in ten years. We [i.e. robot developers] know how hard that is, but they [i.e. the general public] don't."

Across REELER cases, the robot makers almost unanimously agree that popular media portrayals of robots as overly technically advanced are harmful.

Such portrayals of robots exploit evolutionarily evolved tendencies. Research has shown that people automatically ascribe human-like mental states to entities that display certain behaviors. When our dog wags its tail at the sight of us, we interpret that behavior as the dog being happy or excited to see us. Similarly, when we interact with robots, particularly social robots, and see them exhibit particular behavior, we likewise tend to ascribe such internal states to the robots (*see e.g. Eyssel, de Ruiter, Kuchenbrandt, Bobinger, & Hegel 2012; Fussell, Kiesler, Setlock, & Yew 2008; Darling 2017*). Robots like Hiroshi Ishiguro's geminoids, Cynthia Breazeal's Kismet, and Invo Labs' Pleo are all examples of this.

> **Anthropomorphism:** *The ascription of internal states characteristic of humans (such as emotions) to non-human entities (such as animals).*

Most recently, Hanson robotics' Sophia garnered attention world-wide for its realism. It has visited the UN and even gained Saudi-Arabian citizenship (Sharkey 2018). These robots all exploit the tendency of humans to anthropomorphize entities exhibiting particular behaviors, even though they are, technically speaking, *just machines* running more or less sophisticated programs – and in some cases seem autonomous while actually being remotely (limb and voice) controlled by a person in an adjoining room (possibly Sophia is also sometimes controlled in this way, or like other human-like robots she can be pre-programmed to answer specific questions). When confronted with robots like professor Ishiguro's doublegänger, which gives the impression of being an entity with full autonomy like the professor himself, it is easy to forget that the display of autonomy is a product of careful staging by the producers. Even if professor Ishiguro's laboratory makes no secret of the technology behind the lively robot engaging in very human-like conversations, it is easy to forget that it is controlled by a human from another room. If not directly controlled by humans, humanlike robots, like most other robots depend on some kind of pre-programming (even when 'self-learning'). They run on the same basic equipment (sensors e.g.) as all other robots and would go nowhere without a battery, which has to be provided and charged by their creators. Robots that are not run directly from behind the scene by humans (wizard-of-oz technology) would soon become a boring conversationalist, if programmers did not continually work to update their software. And, humanoids would be of no interest if the human beings, who interact with them, are not willing to be mystified, and disregard those of the robots' remarks that are nonsensical.

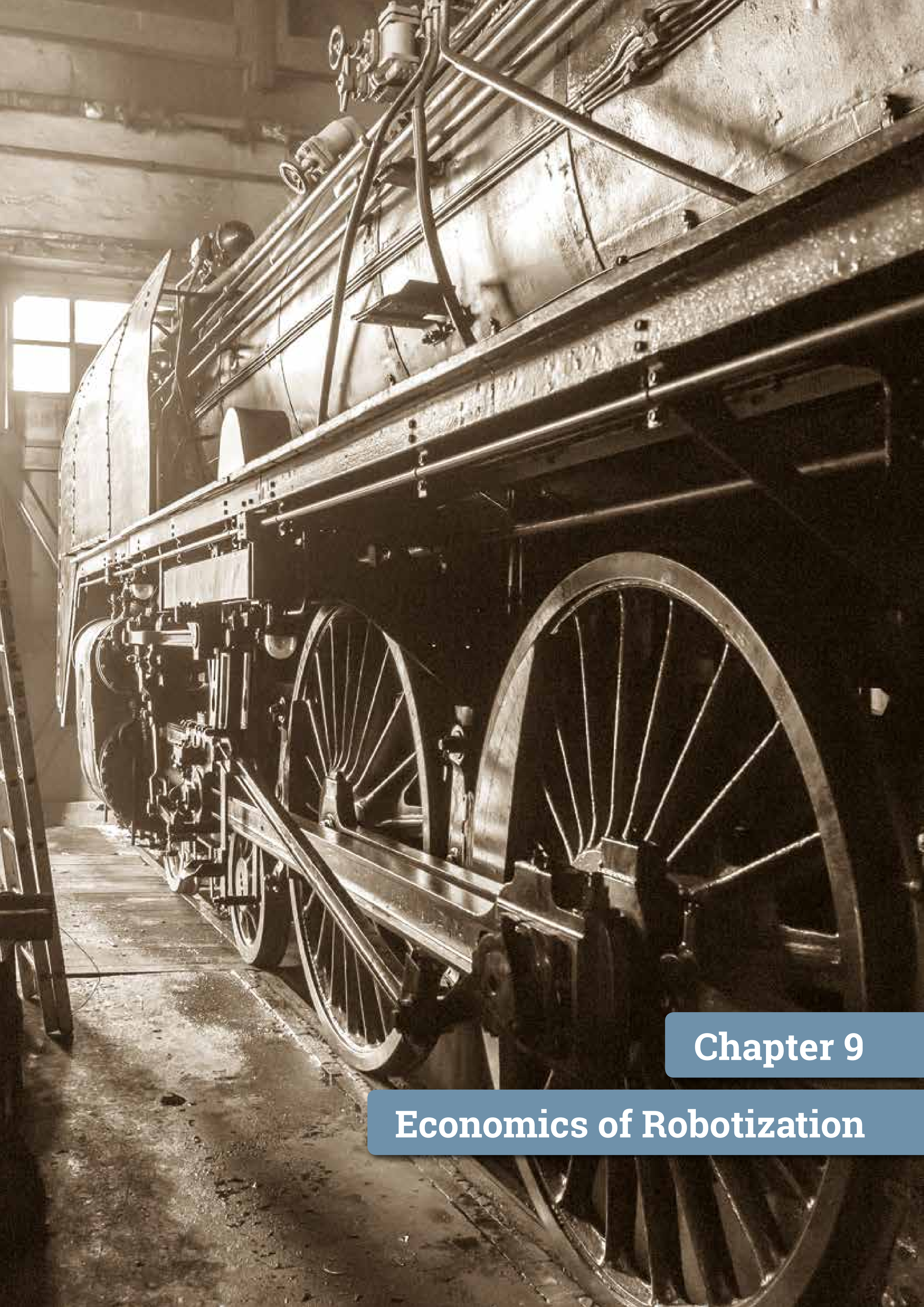
Robot makers, both in our interviews and in public, often express a wish to distance themselves from exaggerated public media representations of robots as more technically advanced than they currently are. Therefore, it is worth pointing out that promotional content produced by application experts at the behest of robotics companies can end up reinforcing that same imaginary when actively exploiting human tendency to anthropomorphize.

8.5 Concluding remarks on Imaginaries

All affected stakeholders are exposed to imaginaries of robots. However, those who actually experience robots soon get a new perspective closer to the one shared by robot developers: that robots are machines. However, also within the inner circle of robotics we find policymakers and ethicists who deal with robots as if they were a kind of new species which can be attributed moral agency. None of the robots studied in REELER, across all cases, have warranted this kind of discussion. Apart from the appearances of the humanoid robots (in e.g. BUDDY and ATOM), the robots look like machines – and even the humanoid turned out to run on the same types of materials as the machinelike robots. Debating robots as moral agents thus seem far from the debates REELER can identify as needed, when considering robots in the daily lives of humans. Many issues tied to affected stakeholders can be seen as a clash between expectations. The distantly affected stakeholders, who have never seen a robot, simply envision robots to be as agile and intelligent as humans. Consequently, it comes as surprise when a robot is, for instance, much slower than a human (*see 10.0 Meaningful Work, section 10.2*). If the concept *autonomous* is connected to being self-ruling, then the robots we have seen in REELER are not autonomous nor have a free will. Humans are always involved, also when robotic systems are described as free of direct human control. In light of this, we argue for a reality check (for instance helped by alignment experts, as presented in *12.0 Human Proximity*). Public discussions of robots have been too preoccupied with discussions pertaining to the sort of robots our interviewees criticize as being fictional, conjured up by public media. Instead, REELER wish to direct attention to discussions about robots that are real and currently causing real good and posing real problems in workplaces all over the world.

Chapter 9

Economics of Robotization



Based on my experience, and also what I have heard from others, it's taking longer than we expected [to get a robotizised society], but at the same time, it's going to have a larger impact than we expected. It's more complicated and has a greater influence than we had expected. It alters the industry structures and cooperation models, it changes who is the leading player and who has power and influence.

(Dan, architect, affected stakeholder, WIPER)

◀ Robotization presents familiar struggles but also unprecedented challenges when compared with previous eras of industrialization (like the introduction of the steam engine).

9. Economics of Robotization

Motives of employers, impact on workers, and interventions by governments

You will find here

- Overview of elementary competitive forces driving robotization
- REELER's conceptual framework on structural change of the sectoral composition of economies
- Overview of simulation results of REELER's labor-economic computer model
- Overview of possible policy measures

You will acquire

- Awareness of how unfettered competition in capitalist economies drives rationalization and robotization
- Awareness of the effects of robotization beyond substitution and job loss
- Awareness of how the structure of the labor market, income distribution may change due to robotization
- Awareness of how policy measures may affect the labor economic impact of robotization

The last couple of years, inventions in artificial intelligence (A.I.), electromechanical actuators, batteries, etc. have made robots more nimble, smart, and versatile. With that, the number of applications of robots and the number of sectors thus actually using, or able to use, robots have increased. In fact, robotics (and artificial intelligence at its core) may well be a new **general-purpose technology** (Lipsey, Carlaw, & Bekar 2006) that will change the global economy and possibly society at large. Given that robots (and AI) are not only complementing but also replacing human labor, concerns are raised about the future of work both in popular media and academic literature (Brynjolfsson & McAfee 2011; Ford 2015; Frey & Osborne 2017). Robots may displace human labor at such a scale and at such a rate that mankind may converge to sustained mass-unemployment, it may be the 'end-of-work'. Recent figures show that the business-to-business sales of both industrial and service robots indeed is ramping up rapidly (International Federation of Robotics 2018).

General-purpose technology: *Technology with applications in many sectors, a major impact on economic growth, and transforming society. Examples are smelting of ore, writing, the steam engine, electricity, the computer, the internet.*

This chapter takes a comprehensive view on the economics of robotization. Section 9.1 elaborates on the rationales for firms to develop and apply robots, which are essentially common cost economics and strategic interests. Section 9.2 is concerned with the impact of robotization on individual workers in terms of employment, work availabilty, skill requirements, and income. Section 9.3 provides alternatives for the 'end-of-work' scenario and highlights how robotization also causes the emergence of complementary tasks, new occupations, and even new sectors. Section 9.4 provides policy interventions to regulate the adoption of robots and/or mitigate the impact.

Given the scope of these four interlocking topics (firm rationales, impact on workers, structural change, and policy interventions), complexity and actuality of the subject matter, and the ongoing academic discourse, this chapter is to be seen as an introduction to the topic. Although this chapter mostly addresses the *macro-level rationales and impact* of robotization, it is acknowledged that there are potentially far-reaching consequences for individuals. Where deemed illuminating, results from REELER case studies on *micro-level impact* of robotization on work have been included in the form of vignettes or quotations.

9.1 Firm rationales for robotization

> **Robotization:** *To convert for automated operation or production by robots or robot-like machines.*

The last couple of decades, **robotization** mostly took place in manufacturing sectors. As most manufacturing sectors are mature and have dominant designs for products and well-articulated demands, firms are generally engaged in fierce rivalry, often even across the globe. Following the standard strategic management framework of Porter (1979), firms thus have to cope with several competitive forces. Notably, if one firm succeeds in lowering production costs by adopting robots, direct competitors also look for cost advantages through production rationalization and robotization or, alternatively, soften competition by product differentiation, niche creation, alternative business models, etc. A more refined look is provided here. The competitive forces are also at work not only in sectors applying robots, but also in sectors involved in developing and building robots. Existing and newly entering robot developers and builders also look for new (commercially viable) applications of robots, means to lower the costs of robots they develop, or even innovative business models. A short description of the robotics sector is included in this chapter (*see also 2.0 Robot Beginnings* for a more detailed discussion of the rationales.)

9.1.1 Cost competitive pressures and production rationalization

There are multiple reasons why firms acquire robots (or *develop* them in-house) for application in their own production processes. Firstly, robots may be part of process innovation to increase the productivity, reduce dependency on human labor, lower unit costs (taking into account purchase, manufacturing, maintenance, and envelopment costs), differentiate products from those of competitors, etc. Note that robots may be part of a flexible production system allowing so-called mass-customization. Secondly, instead of changing firms' products or production processes, robots may (help to) provide *new* services and enhance services readily provided to customers that are complementary to the products. Thirdly, firms may seek to cement their reputation as technological frontrunners, being at the frontier of technological developments, etc. In this case, competitive advantages stem from marketing and 'window dressing' rather than actual competences or product features. Fourthly, a firm may have a subjective preference for technological solutions without (economic) justification.[1] Fifthly, for the (supposed) sake of workers or because robots may be more precise, can work in harsh conditions, and perform tasks deemed to be too dangeroues for humans (e.g. firefighting or bomb disposal).

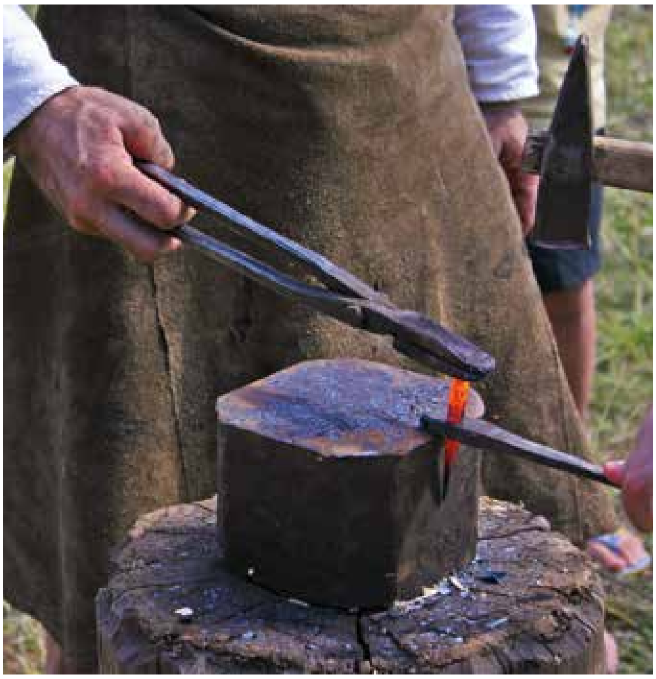
At present, and notably for industrial robots, firms seem to buy robots for the first reason, i.e. robotization is part of process innovation and **rationalization of production**.[2] Arguably, this takes place primarily in relatively mature industries. After all, during the inception phase of the industry lifecycle (Jovanovic & MacDonald 1994; Klepper 1997), entrepreneurial firms enter the young industry and mostly seek to develop new products and place their products in the market. Generally, the variety of product technologies is high, firms are still frequently innovating their products, and demand and production volumes are low. As there is considerable uncertainty about the popularity of products and demand is not well-articulated, firms are not sure whether they will even survive the 'product shake-out' and are hence reluctant to invest in production equipment [3] such as robots. After the product shake-out and emergence of a dominant design, a relatively small number of firms is still active in the industry and there is a substantial market demand for their products. As customers' preferences for certain product features are now more articulated, product innovations become mostly incremental. Given that the variety of and technological differences of products are relatively low, firms are mostly engaged in encroaching upon competitors' market shares through price competition, gaining access to (geographically) new markets, marketing, etc. Moreover, given that products are similar in the mainstream market segment, customers will go for cheaper options. This forces firms to engage in price competition, lowering prices, rationalizing production to lower costs, or rather face a decline in market share, financial losses, and ultimately bankruptcy. So, upscaling production, progressive rationalization of manufacturing processes, and designing an integrated process of production steps may be required not to be 'weeded out'. In short, competitive forces have firms first attend to product innovation to survive the product shake-out and then attend to process innovation to survive price competition. Sometimes, the cost advantages of using production equipment over human labor are so great that rationalization of production and further mechanization becomes an obvious choice, as in the

> **Production rationalization:** *Increasing the efficiency of an existing production process by changing the division of labor, redefining production steps, and introducing alternative production technology (such as robots).*

1 Terms associated with this are 'technological solutionism' (Morozov 2013) and 'techno-chauvinism' (Broussard 2018).

2 The fabled example is that of a pin factory in which workers specialize in particular production steps (thus become more dexterous), have no task switching costs (such as time to take different tools), and separate tasks requiring highly skilled and generally highly paid workers from tasks requiring less skilled workers that can be paid a lower wage. The concept of division of labor is mostly associated with Adam Smith (primarily for economic growth). However, it is particularly Charles Babbage further rationalizing the organization of factories. See the extensive historical, conceptual discussion of the concept in Groenewegen (2008). For the original work see Babbage (2009[1832]).

3 Note that advanced production equipment (such as robots) or complementary services (provided by robots) may add a competitive edge to certain products and thus increase chances for firms to survive the 'shake-out' at the end of the inception phase. To our knowledge there is no literature on this though.



Rationalization is exemplified by the mechanization of nail production in the 20th century, where an expert blacksmith could produce 2300 nails per day, compared to a machine at 250 nails per minute.

case of the mechanization of nail making. Prior to mechanization, nails for woodwork and carpentry were made manually by blacksmiths. An expert blacksmith, who had never done anything apart from making nails, would be able to produce at most 2300 nails *per day*. And it was a tiring and dull activity. In the early 20th century, machines were introduced that manufactured nails from iron wire at a rate of 250 nails *per minute*.

So, from the lifecycle perspective, firms in mature industries seeking to produce mainstream products are forced to engage in production rationalization, process innovation, and considering robotization. Even in industries that are mature for decades (e.g. automotive), firms may well be urged to further deepen automation due to market particularities (e.g. changes in customer demand), competitive circumstances (e.g. competitors offering equivalent products at lower prices), strategic decisions (e.g. differentiation or diversification of product portfolio), changes in laws and regulation pertaining to wages, working conditions, etc., technological (dis) integration within the value chain (e.g. suppliers or customers calling for synchronization of production, reaping benefits of progressive division of labor), and the advent of new management scientific methods (e.g. rise of Fordism).

Note that, in the sector of application, from a competitive point-of-view, firms mostly introduce robots to increase productivity (lower unit costs, higher efficiency). Of course, this does not mean all robots increase productivity. This section started with providing a few other reasons for adoption of robots: window dressing as tech savvy firm, technology solutionism, reducing labor dependency, for the sake of workers, etc. Moreover, robots may allow provision of complementary services, manufacturing higher quality products, work in harsh conditions, etc. Even if the total cost of ownership of robots exceeds the cost of labor, robots are introduced if they are believed to yield a 'sufficiently higher' productivity and thereby lower unit costs, or whenever robots yield more competitive products or services (e.g. in terms of quality) and thereby a 'sufficiently higher' revenue. As such, there are situations in which robotization is a trade-off. Table 1 shows the rationality of robotization when the operational performance in terms of unit costs is pitted against another performance characteristic.

Even in cases when substitution is economically rational, there may be reasons not to adopt robots, e.g. envelopment (changing physical space to facilitate/accomodate the operations of the robot) is not possible, there is worker resistance, it violates certain laws, etc. Resistance, regulations, etc. may have to do with the destruction of jobs, deterioration of working conditions, changes in the task set or valuation of skills, etc. These topics are discussed in the next sections and in *10.0 Meaningful Work.*

Given the role of wages and total cost of ownership, there is a close relationship of the economic rationales of robotization and offshoring production to low wage countries. For firms producing mainstream products and not differentiating their products, price competition forces firms to reduce first pro-

Table 9.1. Rationality of robotization in a two-dimensional performance framework.

		Operational performance of robot compared to human worker	
		Less productive/ slower. Higher cost per unit product.	More productive/ faster. Lower cost per unit product.
Additional performance characteristics	(Yet) inferior solution (e.g. inaccurate, requires envelopment, ample labor, underdeveloped, etc.)	Technology solutionism? Window dressing?	Trade-off
	Superior solution (e.g. precision, complementary service, operates in harsh conditions, resolves labor shortage, preferred by customers)	Trade-off	Substitution is economically rational

duction costs and subsequently labor costs in both cases. As such, European firms in competitive manufacturing sectors seem to be faced with two alternatives: either lowering unit costs by offshoring production to low wage countries or by robotization of production, as mentioned by a robot developer participating in the REELER research.

> *The need of higher productivity is a reality for different sectors. So, this increase of productivity and the cost of the human operator is higher, in particular in Europe. So, there is not the choice of the robot versus the operator: It's no work in Europe versus having the work in Europe.*
>
> (Emilia, director of research and innovation, robot maker, COOP)

For monopolists, firms serving niches, or firms enjoying strong scale or scope advantages, this may be yet somewhat of a rhetoric, but the cost economic and strategic management arguments reveal that robotization may thus 'save' European jobs. In the past, many manufacturing jobs were offshored (and often also outsourced) to low-wage countries such as China. Increasing wage levels in these countries and mounting logistic costs already drove de-offshoring/ reshoring tendencies. Now, with increasing sophistication of robots and a drop of prices of robots, reverse-offshoring production activities becomes economically attractive. So, robots may make it viable to onshore production again. However, instead of using labor intensive manufacturing jobs, the jobs are done by high-tech robots and require high-skilled employees. A touted example is that Adidas de-offshored the production of trainers (The Economist 2017) from China to Germany

9.1.2 Rationales for robot research, development and production

This section only provides a brief view of the robotics sectors. Extrapolating the sales figures on robots of the International Federation of Robotics reported earlier in this chapter, the outlook for firms conducting research into, developing, and building robots (and robotic parts) is favorable. However, the robotics sector is multifaceted and diverse. So far, the lion's share of sales is still industrial robots (e.g. automotive, manufacturing, warehousing) and these robots are technologically rather mature and produced by large, established firms. However, currently, the sector is experiencing a swarm-in of many (small) entrepreneurs engaged in research, development, and sometimes already commercial sales of robots in sectors such as agriculture (e.g. milking robots, harvesting robots, precision farming), healthcare (e.g. surgery), construction (e.g. brick laying), maritime (e.g. pipe line inspection), etc. Moreover, the robotics sector is characterized by a rich set of knowledge institutes conducting mostly research and building early prototypes often in collaboration with entrepreneurs or on component technology with large established firms.

In general, the developments in the sectors of production equipment builders (such as robots) directly affect the sectors applying that equipment. While traversing their own industry lifecycle, many robot developers are engaged in product innovation, looking for new applications for robots and opening up new niches/ sectors, rationalizing their own production, and reaping scale advantages (e.g. by standardizing, modularizing, introducing commonalities across robots). Clearly, for reasons outlined before, firms in sectors applying robots are likely to have to respond to innovations in the robotics sector or even actively collaborate with robot firms to pre-empt competitors in their own sector. Indeed, robot developers may thus trigger 'deepening automation' in firms in 'robot-applying sectors', while competitive moves of firms applying robots may trigger new robot developments.

Interestingly, some robotics companies actually have the explicit goal of making robots that are cheaper than humans for their customers:

> *So, the idea of the company is actually to create robotics that are accessible. So, it's not as expensive as people - I mean, it's still not going to be cheap yet, but it is acceptable and it's affordable and more companies can employ robots.*
>
> (Felix, CEO advisor, robot maker, WAREHOUSE)

Given the increasing competition and maturation of the industrial robotics sector, some industrial robotics firms specialize in subsystems (e.g. grippers, sensors, actuators), others in specific applications (e.g. painting, welding, assembly, cutting, packaging, SCARA material handling), while yet others differentiate by offering modularized designs or rather customization. Arguably, successful improvement of robot features (e.g. refined sensors, actuators), a lower unit price of robots (e.g. due to upscaling of production), enhanced functionality (e.g. tailored to sector specific applications), and alternative business models (e.g. renting or leasing robots)[4] will speed up the adoption of robots in existing and new sectors. So, the increasing competition drives product innovation, differentiation, upscaling, etc. in the robot making sectors, which in turn drives process innovation in the applying sectors.

Given the many promises on process innovation in the applying sectors, the EU funds quite a few robotics projects. In fact, REELER's analysis of the CORDIS database reveals

4 See for instance the company Smart Robotics in Best, The Netherlands: https://www.smart-robotics.nl/

that across close to 600 robotics research projects in the 7th and 8th Framework combined, more than 1500 institutes and firms received more than €25k, more than 250 institutes and firms received more than €1M, and more than 25 institutes and firms received more than €10M in funding. The biggest receivers consist of major research institutes such as Fraunhofer, DLR, DFKI, and Max Planck Institute in Germany, the IIT and LFCA in Italy, the INRIA, CNRS, CEA in France, etc. These are followed by major universities and colleges such as the SSSA and UPisa in Italy, TUM and KIT in Germany, ETH Zürich, the Imperial and University College in England, the three technical universities in The Netherlands, etc. to name just a few. The financed projects range from early stage (low Technology Readiness Level) projects with a variety of applications (e.g. in agriculture, rehabilitation, home appliances, surgery, firefighting, maintenance), fundamental research on topics like swarms, communication protocols, nanorobots, etc., or refinement of existing components such as grippers or sensors.

In several of the REELER cases, it was found that robots are sometimes expected to be neither better, nor cheaper than humans but are developed anyway. Firms involved may have been motivated by technological deterministic or techno-chauvinistic points of view , and because there was risk capital and public funding available for robot development. The rationale of funding organizations may thus be to gain technological expertise, build a collective knowledge base, establish an innovation network for future projects, establish technology transfer, develop early prototypes to extend, and ultimately cascade into additional developments that are expected to be economically viable or contribute to society.

9.2 Impact on workers

Over the past centuries, there have been several waves of innovations that enhanced the productivity of laborers. Generally, processes of mechanization, automation, and computerization increased the agricultural yield per farmer per acre, the number of products produced per worker per hour, the value added per worker per task, etc. As mentioned in *10.0 Meaningful Work*, there are several potential effects for individual workers in workplaces adopting the productivity-enhancing, labor saving technologies. Firstly, higher productivity per worker means that fewer workers are needed for the same output. Redundant workers may be laid off or see their wages are lowered. Secondly, with the introduction of technology, the sets of tasks executed by workers may change, e.g. may become reduced to residual tasks necessary to keep the machines running or may change to require differ task to install, program, and maintain machines. As production and service tasks change and/ or new ones are introduced to reap complementarities with the robots adopted, the remaining jobs are expected to change qualitatively. Thirdly, given the change in task sets and required skills, the wage of workers may change: workers with scarce, advanced skills in high demand will generally have higher wages than workers with basic skills and/or in low demand. Fourthly, newly unemployed may look for jobs in the same sector or (may be forced to) look for jobs in other sector(s) that may require different skills. This underlines the importance for education or training-on-the-job in reskilling (*see also 10.0 Meaningful Work*).

9.2.1 History: a reason for optimism?

Illustratively, when steam-powered weaving looms and other 'frames' were introduced in factories in the early 19th century, British craftsmen, weavers, and textile workers thoughtfully [5] protested against mechanization of their work, the destruction of jobs, changes in skills required and tasks to be performed, and the wages paid. Figure 9.1 shows that, over the past 170 years, the unemployment rate remained relatively low, real consumption wages increased, and the hours worked decreased. So, superficially, and disregarding external costs such as environmental pollution, the impact of mechanization and progressive industrialization may have had mostly positive effects.

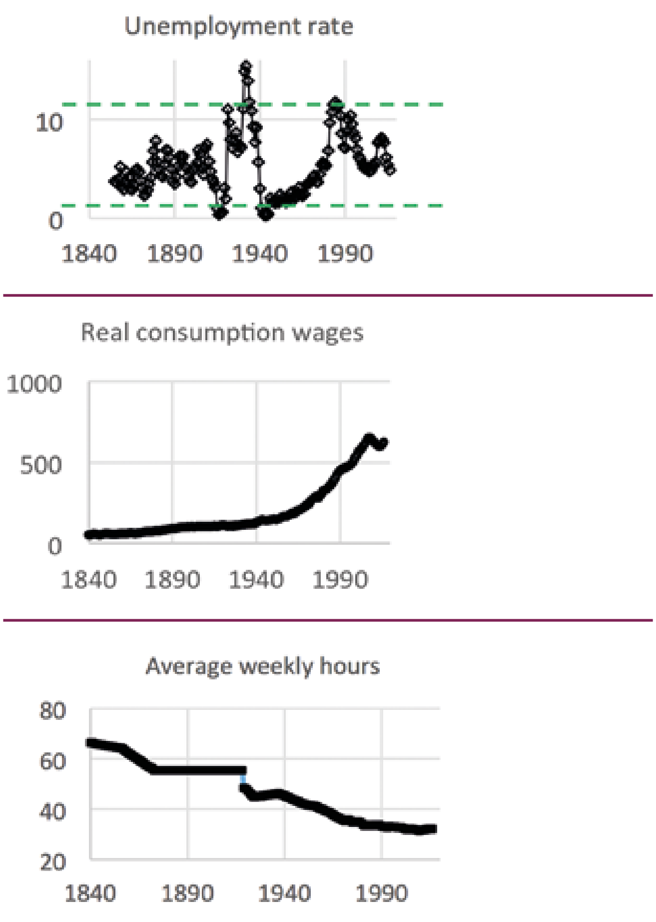


Figure 9.1. Unemployment rate, real consumption wages, and average weekly hours worked in Great Britain over the years 1840–2016. Source: Bank of England, Millennium of Data v3, dataset A48, A50, and A54. (Data visualization by Ben Vermeulen)

5 In the historian Frank Peel's entertaining account of the Yorkshire Luddite movement, however, the mere loss of jobs seemed to be the prime reason for the uprising and the 'degradation' of the highly skillful workers finishing cloth ('cropping') the secondary reason. See: Peel (1888).

Robotization may affect professional pride, the care and sense of ownership tied to the product of one's labor. (Photo by Kate Davis)

While there were fears that steam-powered machines would replace labor, cause mass unemployment, and have people live at subsistence levels, these figures suggest that the negative outlook was unwarranted --at least in the long run. Why would it be different in the case of robots? (Mokyr, Vickers, & Ziebarth 2015). In this chapter, we discuss various scenarios on the development of employment and analyze how countervailing forces, structural chance, policy interventions, and education may contribute to sustaining high levels of employment.

However, although ultimately the industrial revolution brought prosperity to many, the living conditions of factory workers in the 19th century were poor. Indeed, throughout that century, there were repeated calls for social and economic reforms, not least by Marx and Engels. Not before the 20th century did living standard improve substantially, particularly in Western countries. Nevertheless, even now, the Western countries still have 'working poor' and society is facing further stratifications with a growing 'precariat' living in uncertainty and near subsistence levels (Standing 2014). Robots and AI are expected to have a potentially tremendous impact on employment, also on a global scale. Moreover, like before, there are economic forces that may increase income inequality and stratify society, both within nations, but also across the globe.

While the previous section revealed how the competitive forces in capitalist economies drive production rationalization and robotization, and this may (again) cause stratification, inequality, etc., it is important to note that progressive robotization is not inevitable. Further, technological development may still be regulated, and certain adverse effects of adoption of robots may possibly be mitigated politically, for instance, through a robot tax, universal basic income, etc. That said, if mass-robotization does indeed occur and mankind ends up in a situation with mass-unemployment, yet other political and economic reforms may (again) be needed to redistribute wealth, tax capital goods, re-educate and upskill the unemployed, and safeguard the well-being of citizens in general. However, arguably, contemporary economies are quite different from those in the early 19th century.

9.2.2 Susceptibility to robotization

Much of the popular debate focuses on which jobs will be robotized and what happens with the *total rate of employment.* As discussed before, there are various reasons for further rationalization of production processes and robotization of certain production steps. Following straightforward economic rationales, firms' separate tasks requiring highly skilled, highly paid workers from tasks requiring less skilled workers that can be paid less. Until recently, the labor economic literature concerned with technological change argued that particularly *low-skill jobs* would be at risk of mechanization, automation, and now robotization. Nowadays, though, it is argued that technological substitution primarily occurs for *routinized tasks* in stationary, predictable environments. Arguably not by coincidence, robots were first introduced in Fordist factories in which time-and-motion-studies had already organized work in short-cyclic, repetitive tasks: they could easily be executed by robots. Recent studies revealed that such routinized tasks are typically found in middle-skilled jobs (Autor, Levy, & Murnane 2003; Ford 2015). Jobs which require refined perception and physical dexterity, creative intelligence/ improvisation, or social intelligence, regardless of whether they are low-skilled or not, are less at risk of replacement (Brynjolfsson, & McAfee 2011; Deming 2015; Frey & Osborne 2017). Hence, one could argue that robots (and AI) will take over routinized tasks, while tasks requiring essential human qualities are left to humans (*see section 9.2.3*).As robots become increasingly nimble, learn to handle more complex tasks, and can cope with more dynamic environments, more and more tasks will become susceptible to robotization.

9.2.3 Qualitative transformations and labor mobility

Apart from the debate on the total rate of employment, the Luddite uprising already illustrated that people, do not just work to make a living, but seek to engage in meaningful activities, which requires and values their skills. For that reason, we do not only discuss how robots affect the rate of employment, but also the *types of jobs* and notably the *tasks* subsequently performed by humans and the *skills* required.

Qualitative transformation: *A notion underlining that not only 'having a job' matters when thinking of the impact of robotization on employment, but also the type of work, the skills required, and the job satisfaction.*

A popular rhetoric in favor of robotization is that robots ultimately do the work deemed dull, dirty, and dangerous, which was supposedly ungratifying to begin with (Kaplan 2015). Thus, workers relieved by robotization may then focus, willingly and happily, on meaningful, gratifying work requiring supposedly distinctly human qualities such as emotional and social intelligence, creativity, and physical dexterity (e.g. Deming 2015; Brynjolfsson & McAfee 2011). The argument is that robots effectively 'rehumanize' work for people, and, implicitly, that mankind should rejoice in the coming of robots. This 'rehumanization argument' is nicely illustrated in the quotation of one of the interviewed stakeholders:

Rehumanization argument: *Line of reasoning arguing in favor of progressive robotization because robots can and may take over dull, dirty, and dangerous work deemed ungratifying and thus free up humans that can then focus on work requiring supposedly distinctly human qualities. Robotization thus facilitates rehumanizing work of people to do supposedly gratifying, meaningful work rather than supposedly ungratifying, meaningless rationalized production activities.*

> *It's great that machines do a lot of the hard work we had to do in the past, but if we liberate a lot of people from that work, we should use these creativities, energy, this time, for other things; there are a lot of things to do in the social way, help people, manage the environment and reflect about that.*
>
> (Emanuel, exhibition coordinator, affected stakeholder, BUDDY)

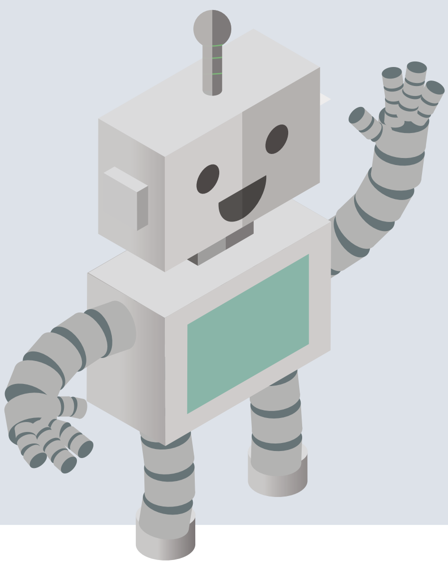
Robots may be adopted out of necessity if there are no workers to do supposedly dull, dirty, and dangerous work (*see section 9.1.1*). Robots may also be adopted to cope with regulations on working conditions that protect people from doing particular dirty or dangerous work (e.g. lifting very heavy elements), or highly repetitive and dull work (e.g. extremely short cyclic work) (*section 10.3. in Meaningful Work* for a counter-perspective involving post hoc explanation of relief of workers). Indeed, the introduction of robots may resolve labor shortages in production, which may itself be caused by poor working conditions, low wages, legal complications, etc. Though robotization of such jobs and tasks are often seen as relieving the worker, robotization need not be the only solution, just as assumed dull or repetitive tasks may not be perceived that way by the workers.

While robots may take over some jobs entirely, it is more likely that robots perform certain tasks, and that workers get an altered set of tasks. Indeed, the introduction of robots in the workplace may have a great impact on the tasks executed and skills required – see the story from the field "A construction robot" below. It may well be that workers get new tasks assigned that are complementary to the tasks of robots. These tasks may be more complex and require upskilling, but this is not necessarily so. On the other hand, the introduction of robots (and the rationalization of production possibly required for robotization) may also make the tasks less complex, more repetitive, even more dangerous (and unintentionally countering the rationale for introducing them in the first place). Think for instance of skilled masons at construction sites that became operators feeding bricks to robots, who perform their old tasks. In this case, robotization may actually introduce rather than eliminate repetitive tasks.

STORY FROM THE FIELD:

A construction robot

In WIPER one of the robots aim to change the work for people at construction sites. Before the introduction of the robot, two or three workers used to coordinate to install heavy doors in commercial spaces, but now the task of lifting is taken over by the WIPER robot (a prototype still under development). The shift from multiple workers lifting and adjusting the doors to a robot lifting the doors and one worker manipulating the robot has required changes in the workers' skills, their rhythm of work, and their collegial relations. Instead of laboring together with his colleagues, now one man or woman can manipulate the door using a controller attached to the robot. Previously the workers felt a sense of pride when installing doors that swing perfectly into place. Now, the robot acts as a mediating device between the worker and the completed task, which has affected the workers' professional pride. On the other hand, the robot also demands new skills of the workers. The construction workers had to learn to steer the equipment and smoothly position the door using the robot. For new operators, the robot can perform rather shakily, which can be unnerving when handling for instance large glass doors. But the workers who received hands-on training became confident enough to try installing some doors with the assistive device, whereas those who'd only seen a demonstration and received a training guide abandoned the tests with the robot. Thus, a robot can significantly alter existing tasks and demands for skills both positively and negatively.



(Based on interviews from the WIPER case)

Even if robotization would change human work to consist of tasks requiring qualities currently cosidered to be uniqely human (e.g. sociality and creativity), this is not necessarily desirable from the perspective of the individual worker. Indeed, an interesting finding in the REELER project is that robot developers, firms applying robots in production, policymakers, labor economists, etc. suffer what is dubbed a 'human quality - meaning fallacy': this is the (possibly) mistaken belief that people *want to* do complex work requiring social skills, creativity, physical dexterity, or general intelligence. However, the REELER data shows examples of people, affected stakeholders, who do not dislike their low-skilled, repetitive, or physical work (*see section 10.4. in Meaningful Work*). As such, the reasoning that robotization of dull or repetitive tasks is universally desirable or that workers prefer to do (what some might consider) more meaningful work is fallacious. While the repetitiveness of assembling tasks may be dull to some, it has a 'pleasant meditative' effect speeding up the passing of working hours to others. While working on a cattle farm is considered dirty by some, it may actually be an enjoyable job to others. And while cleaning windows of skyscrapers is considered dangerous by some, it is exciting to others. Even physically straining work may be considered desirable by some, for instance because such work helps develop a muscular physique (see the SPECTRUS case, for example). Moreover, working a desk job and sitting in a chair all day, doing complex work, or having to do social work may be disliked or considered tiresome by some.

Quality – meaning fallacy: *The (possibly) mistaken belief that jobs requiring more human qualities (notably social skills, creativity, intellect) are considered more meaningful or desirable to or more appreciated by workers.*

A related question is whether there will be enough of these supposedly meaningful jobs? And, given the wider dispersion of automation and robotization, will job creation keep up with increasing rates of job elimination, and will we be able to educate people fast enough to fill new vacancies? (Goldin & Katz 2008; Acemoglu & Restrepo 2018a). These topics are discussed in more detail in *section 9.3*.

9.2.4 Income inequality and geographical division

A primary concern of mechanization, automation, robotization, etc. is that it widens the gap between the rich and poor. Given that routinized tasks are more prone to be taken over by robots, certain jobs are more likely to be affected and possibly vanish completely. Due to predispositions and personal aptitudes, those newly unemployed may struggle to re- or upskill to compete with an increasing pool of low- and middle-skilled unemployed competing for scarce low-skill jobs, which in turn would depress wages. Or, if they succeed in re- or upskilling, they may face an increasing pool of well-educated unemployed workers competing for increasingly scarce high-skill jobs. So, due to limited geographical and labor mobility as well as increasing competition for jobs, we may see an increasing class of people grappling for a low income. This may drive progressive stratification of society into the classes (e.g. Standing 2014; 2011) 'precariat', 'technical middle class', 'elite', etc. A related perspective is that particularly *middle*-skill, white-collar jobs with routinized tasks are subject to robotization. Consequently, there is polarization of the labor market, with a growing gap between a small group of highly paid, highly skilled workers and a big group of workers with low-paid, low-skill jobs (Autor, Katz, & Kearney 2006; Goos & Manning 2007; Goos, Manning, & Salomons 2009). So, robotization may stratify societies, i.e. may create classes of people with different wages and opportunities, purely based on different capabilities, existing skills, and education.

These stratifying and polarizing forces also work across the globe. Given differences in the sectoral and occupational composition of economies, the impact of robotization may greatly differ across nations and effectively exacerbate the 'North-South divide'. Concretely, robots may be developed and built in the "North" countries and (also) applied in "South" countries. While widely varying, developing economies ("South") may be affected by robotization in several ways. Firstly, the capability to arrange technology transfer and absorb new technology may be limited due to an as of yet limited knowledge base. As such, developing economies may miss out on potential benefits of researching, developing, and building robot technology. Secondly, as the developing economy's labor force that is part of a global production network is possibly employed in labour-intensive manufacturing or routinized service industry, those workers are (1) at risk of becoming unemployed due to rationalization and robotization or even reverse-offshoring of production, or (2) facing wage reductions in competition with robot technology that becomes cheaper. Thirdly, if reverse-offshoring were to take place, production networks are dissolved, which also severs reverse knowledge sourcing channels. And particularly these ties in production networks were considered important channels for technology transfer (*see e.g. Ernst 2002*).

Taking robot patents as indicator of their locations,[6] REELER research revealed that firms in the robot making sectors are located in countries such as the U.S.A., Japan, China, South Korea, and Germany. However, sectors *applying* robots may be located in other, even peripheral countries. In the case of Europe, several North-Western countries may develop and build robots that, when applied, destroy jobs in Southern and Eastern countries. Thus, robotization may counteract the European Union's goal of inclusive growth. Such an emerging geographical disparity is well-conceivable for several sectors – not least agriculture. In agriculture, however, the introduction of robots may in fact increase productivity in the more advanced production systems rather than in less advanced production systems.

Inclusive growth: *A central policy objective of the European Union emphasizing that all classes of society across all nations should benefit from economic growth.*

6 European Patent Office patents, excluding WO and EP patents.

STORY FROM THE FIELD:
Agricultural robots

REELER's anthropologists made a case study of agricultural robots. One of these agriculture robots was cooperatively developed by a number of institutes and companies mostly in north-western Europe. The robot is being developed for and tested in specific areas in these countries. However, REELER's researchers conducted interviews in wider Europe to explore the potential impact of that robot on more distantly affected stakeholders, like growers in Spain and Italy, and farm lobbyists in the United Kingdom.

In Italy and Spain, the areas used for farming have different sizes and growing conditions than in Western or Northern Europe. In western parts of Europe, the plots are often large and flat with crops arranged linearly along raised berms, with lower, wide, flat swales between the rows – creating a more predictable map and a more easily navigable environment for a robot to maneuver between the planted areas. Today, these farms are coordinated and managed almost like industries, with collective harvesting and packing arrangements, and relying on labor from the eastern parts of Europe and other immigrant workers. In the southern parts of Europe, we find more small family owned farms on plots that are anything but flat and straight – where the crops are planted in contours over hills and around the occasional tree or rocky outcrop. The field's layout and the growing and harvesting methods are much less predictable than in the large, flat farms to the north. Such farms are incompatible with precision farming in a robotic future.

If agricultural robots increase productivity or efficiency significantly in Northern Europe, Southern European farms may struggle to compete with the crop prices in the North. These developments might also affect migration patterns, as fieldworkers and growers in the Southern parts of Europe and in North Africa may find themselves without jobs. There are unrelated fears in the UK, as Brexit has already led to migrant workers leaving the UK. Large emigration of European migrant workers could leave a labor deficit in agriculture, followed by increasing wages, and thereby food prices. Robots may then be called in to solve the labor crisis, though not without substantial changes in how agriculture is performed. This shows links between robotization and broader societal issues, such as food security, migration, and labor mobility.

9.3 Structural change

The previous sections discussed firms' motives for and activities in production rationalization as well as entrepreneurial robot development including the impact thereof on workers in terms of employment, tasks performed, income, and skills required. At an aggregated level, this brings about a shake-out of firms and job destruction in sectors relying on 'old' technology gradually being robotized, as well as a swarm-in of entrepreneurs and job creation in sectors engaged in 'new' technology, including robots. So, the development of employment, income, and skills takes place within and across different types of sectors. Here, this notion is extended in a multi-sectoral perspective.

9.3.1 Multi-sectoral perspective on the impact of robotization

Arguably, the scientific 'end-of-work' literature, with such prominent proponents as Brynjolfsson and McAfee (2011), Ford (2015) and Frey and Osborne (2017), and some strands of popular media have a narrow focus on the *loss of jobs due to substitution*.

Countervailing force: *An economic mechanism in which the introduc-tion of robots creates work and thus compensates the destruction of work.*

Although firms in some sectors are indeed mostly *applying* robots to increase productivity and reduce required labor and the technological advancement of robots do expand the range of sectors in which robots are (potentially) applied, there also are sectors in which the technological change actually *creates new jobs* (see, e.g., *Hughes 2017; Nathan & Ahmed 2018) or transforms the task content of jobs*. Additionally, there are (indirect) effects on wages, disposable income, and thereby consumption, with consequences for product demand and thereby employment in other (types of) sectors. As such, there is a range of countervailing forces aimed at compensating job loss due to robotization. In short, the main direct 'countervailing factor' concerns increases in demand for skilled labor to build robots, labor demand for complementary skills required to use robots, and increasing demand for labor due to a decrease in product costs caused by robots (for further reading, see e.g. Vivarelli 2007; Autor 2015; Acemoglu & Restrepo 2018b; Vivarelli 2014). Different countervailing forces are at work in different types of sectors. The 'countervailing forces' are cast in a structural change framework based on *different types* of sectors (*see Vermeulen et al. 2018 and Annex 1*).[7]

7 see responsiblerobotics.eu/annex-1

Structural change literature (Baumol 1967; Echevarria 1997; Ngai & Pissarides 2007) studies the evolution of the composition of an economy in terms of sectors, occupations, and (types of) work, notably featuring increasing variety in the sectoral composition and output (Pasinetti 1981; Saviotti & Pyka 2004; 2008). Over the last two centuries, technological change drove the migration of labor from the agricultural sector to manufacturing sectors and later from manufacturing to service sectors (Leontief 1982; Ginzberg 1982). One of the REELER studies (Vermeulen, Kesselhut, Pyka, & Saviotti 2018) proposes a classification of sectors based on the impact of technological change (here: robotization) on demand for labor in certain occupations. For one, there is a definite increase in labor demand in sectors making robots. Think of all the people researching, developing, designing, and building robots as well as implementing these robots in other sectors. Moreover, in the *applying* sectors in which firms buy and apply robots, these robots often do not outright replace workers, but takes over certain tasks. New and complementary tasks that emerge with the introduction of robots are, for instance, programming, controlling, and maintenance of robots, as well as reorganizing production and services. In addition, sectors *complementing* the applying and making sectors (such as the education & training sector, consulting sectors, the legal support sector, etc.) see a transformation in the activities, as people need to be (re)educated to either research, develop, and design robots in (potentially new) production & service environments. Similarly, people need to be (re)educated to (also) use robots instead of tools used previously, and possibly program and maintain these robots.

Structural change: *An economic core concept on how the composition of an economy evolves over time in terms of sectors and occupations, often due to cascading effects of development and application of new technologies.*

On top of the creation and elimation of jobs, as well as changing tasks of occupations, the *income* of people changes. With a foreseen increase in demand for robots, demand for workers in the *making* sectors becomes high, and firms compete for robot developers, such that wages may well increase. In the *applying* sectors, some workers may be replaced by robots and thus become unemployed. These workers may not be able to upskill and may end in low-skill jobs with lower wages or may have to rely on social benefit schemes. In fact, in *competitive* applying sectors, rationalization and robotization may be sought to reduce reliance on skilled workers, which could depress wages. The *complementing* sectors will see a decrease in demand for teachers, trainers, lawyers, production engineers, consultants, etc. specialized in the old technology now being replaced with robots. However, the demand for teachers, lawyers, engineers, consultants etc. with an expertise in robotics is expected to rise, peaking during the transition, and then plateauing at the lower level in the long run enough to replenish natural employment turnover. Moreover, particularly those that are experts in robotics may get higher wages (Vermeulen, Kesselhut, Pyka, & Saviotti 2018; see also Annex 1)[8]. In addition to making, applying, and complementing sectors, there are *competing* sectors, in which firms make technologically different products but that provide services rivalling those in the applying sectors, e.g. the railway sector is competing with road transport of people and goods. Clearly, application of robots in one of these sectors may strengthen the competitive position of firms vis-à-vis firms in these competing sectors due to higher productivity, lower prices, lower dependency on labor, etc. Consequently, the competing sector may see a decrease in product demand, employment, and wages. That said, firms in these competing sectors may respond by investing in research and development to catch-up or even leapfrog. Note that even among the sectors applying robots, there may be sectors competing for the same demand, which probably intensifies rationalization and robotization on the one hand and investments in research & development of new products and production processes on the other hand.

All else being equal, a change in the number of workers employed and the wages they receive across all (types of) sectors reflects in the total disposable income. Part of this income is spent in *spill over* sectors, e.g. on vacations, recreation, sports, entertainment, personal care, lifestyle, luxury goods & services, etc. As such, changes in employment and income are amplified by the effects on the spill over sectors. On top of the developments within and across existing sectors, new sectors will emerge.

The structural revisions and additions to classifications such as the International Standard Industry Classification (ISIC) or the Nomenclature statistique des activités économiques dans la Communauté européenne (NACE) reveal changes in the sectoral composition. However, the institutes behind these classifications only occasionally revise the classifications: the last ISIC revision (rev.4) dates from 2008 and the last NACE revision (rev.2) dates from 2006. The biggest change in both classifications at the time was the addition of a section on ‘Information and communication’, with notably computer programming (including the development of webpages), computer consultancy, service activities (such as webhosting, streaming services, data processing, etc.). Tellingly, these standards refer to robots only in the context of manufacturing for tasks such as lifting and handling in production lines, but not yet in healthcare services, transport & logistics, agriculture, defence, space, maintenance, etc. Many of the currently emerging sectors do not yet have distinct names or clear outlines. Arguably, entrepreneurial activities are likely to revolve around (1) emerging technologies such as data science, artificial intelligence, quantum computing, block chain, internet-of-things, etc.,[9] (2) intangible technology and based on concepts and information content such as e-commerce, social media, computer games, (3) data-driven decision and research support such as fin-tech, drug discovery, etc. and, (4)

8 see responsiblerobotics.eu/annex-1

9 See the World Economic Forum report “Future of Jobs 2018”.

advanced applications of robot technology in sectors mentioned before (transport, agriculture, healthcare, etc.). Under these circumstances, all the jobs in these emerging sectors are newly created and would 'mop up' unemployed workers from readily existing sectors. That said, not all positions in these newly emerging sector can be immediately fulfilled because they require new skills, knowledge, etc. and labour mobility is limited (for a more detailed account, see section 9.3.2). Furthermore, it is unlikely that the majority of newly unemployed, previously working in the applying sector, will find new jobs immediately following their termination.

Table 9.2 provides a comprehensive overview of the effects of robotization, both in terms of employment and income specified for the different types of sectors.

Table 9.2. The sector-occupation matrix specifying how the introduction of robotics affects the number of jobs for the impact-specific types of sectors and (types of) occupations. This is developed in Vermeulen et al. (2018), see Annex 1 Methods and Methodology (responsiblerobotics.eu/annex-1). Note that there are also unrelated sectors that are not or only highly indirectly affected.

		Type of sector				
		'Making'	'Applying'	'Complementing'	'Competing'	'Spill over receiving'
Change in occupations	EXISTING	+ Increase in demand for robotic technology and deepening automation of older 'vintages' of existing production equipment + Increase in demand for upstream component suppliers, and downstream service suppliers	– Pure substitution of workers by robots + Increase in demand due to lower prices caused by increase of productivity of manufacturing + Exploitation of complementarities by adding new tasks or even (specialized) jobs (e.g. maintenance of robots)	– Loss of jobs pertaining to old technology and jobs now replaced by robots (e.g. teachers in vocational studies welding, painting) + Increase of jobs pertaining to robots, to occupations transforming and reaping complementarities (e.g. trainers for maintenance of robots)	– Decrease of employment and income due to weaker competitive position, relatively higher price, lower demand + Increase of employment in R&D for improvements to catch-up or leapfrog (including possibly robotic add-ons)	+ Increase in employment and disposable income in making sector +/– In- or decrease in employment and disposable income in applying, competing, and complementary sectors + Increase in employment and disposable income for higher skilled workers in applying sectors
	EMERGING	+ R&D, innovation, and entrepreneurial activities further exploring & extending robotics + New high-skill and high-paid jobs, notably for exploitation of emerging robotic technology	+ Resources freed up to put to use in creating new products/ services + New applications facilitated by using robotics in production & services. + New occupations due to new ways of organizing, communication, new social processes, etc.	+ For new occupations and new technology	+ Increase in employment in R&D, innovation, exploration & exploitation of new technology competing with robotics	+ Increase in employment and disposable income in newly created occupations in all sectors

9.3.2 Labor mobility & vacancy chains

In the multi-sectoral perspective on structural change, labor mobility is paramount in sustaining (or regaining) high levels of employment. After all, workers need to be able to acquire skills complementary to working with robots in the applying sectors, or workers laid off may need to re- or upskilled to find work elsewhere in the same or another (applying) sector. Moreover, in the making sectors, there is an increasing demand for robot developers and builders. For jobs in the emerging sectors, workers need to acquire advanced skills to produce new (types of) products, provide new (types of) services, etc. (although, of course, also low- and middle-skill jobs are required in these sectors). Moreover, firms might not be able to find skilled and willing workers locally and hence may decide to either relocate activities, offer training on the job, increase wages to attract talent from elsewhere, etc.

> **Labor mobility:**
> *The ability to take up other jobs (possibly but not necessarily requiring other skills), which may, but need not, be in another geographical location.*

In addition to ethnographic studies, REELER has also conducted a study (Vermeulen, Pyka, & Saviotti (forthcoming), and Annex 1)[10] involving an agent-based computer simulation model with firm agents and worker-consumer agents. It was developed to study the evolution of a multi-sectoral, multi-occupational labor market subject to robotization and the moderating effects of several policy interventions proposed in literature. At the core of this model are two interlocking processes driving labor allocation: (1) the competition of firms for skilled workers, which drives wage increases, and (2) the switching of workers to jobs with 'sufficiently higher' wages, i.e. in which the wage gap exceeds a positive threshold. Hereby, a 'market matching process' recursively allocates the most suitably skilled workers to the highest paid vacancies until all vacancies are filled or no workers are unemployed anymore. The workers subsequently spend disposable income on consumption in the economy itself. This basic model reproduces empirically observed wage-price spirals. In addition, there are two independent processes that affect the number of jobs: (1) robotization drives productivity increases, thereby price drops and the laying off of redundant employees (job destruction) across all sectors, and (2) at an exogenous rate, new sectors emerge in which new firms offer new products that (by experimental control may or may not) substitute products offered in already existing sectors.

Unlike the conceptual model of structural change presented in the previous section, the operational simulation model requires assumptions about the job switching propensity of workers as well as the constraints on labor migration in terms of skill gaps accepted by firms. From experiments with this 'admissible skill gap', it is found that the rate at which upskilling is possible moderates the rate of recovery of employment whenever robotization destroys jobs. In fact, this model reveals a phenomenon which was dubbed a 'vacancy chain'. Similar to how hermit crabs swap to bigger shells, employees swap to (better paying) jobs requiring higher skills, thus leaving a vacancy for lower skilled workers to fill, including both job hoppers and the unemployed. Such vacancy chains emerge under a persistent creation of new jobs in new sectors requiring higher skills and sufficient labor mobility (i.e. sufficiently high rate of upskilling). Particularly when the gap in skills is (too) large, initially, suitable workers are scarce, and the offered wages increase.

> **Vacancy chain:**
> *An economic phenomenon (observed in one of our computer simulation models) in which workers move to better paying jobs by upskilling, thus leaving vacancies filled by others with lower skills.*

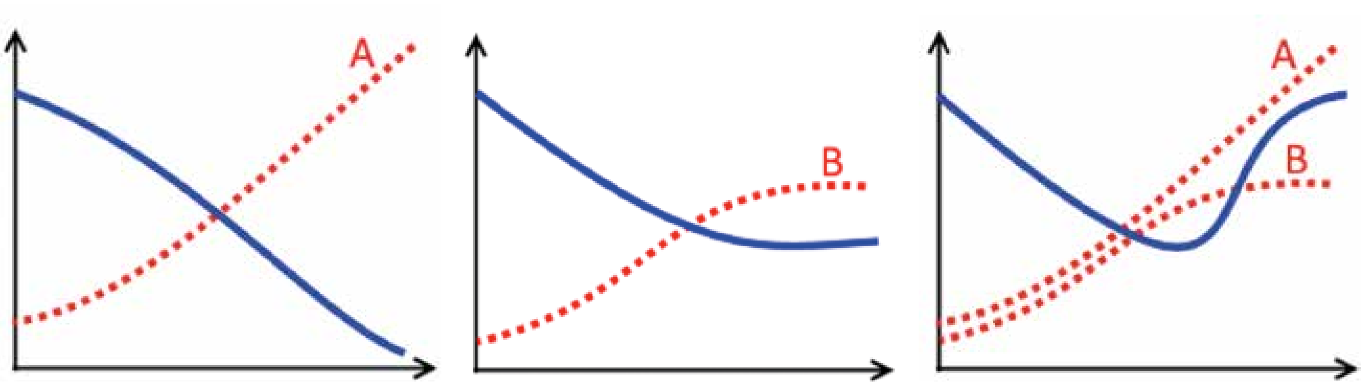
10 see responsiblerobotics.eu/annex-1

The model findings underline the importance of labor mobility and sector creation. However, for analytical purposes, this simulation model has been left highly stylized. Both the mechanisms for upskilling and radical innovation are not modelled. In reality countries differ in the amount of schooling paid for, institutional arrangements for education, labor market regulations, innovation policies in place, etc. In spite of this, one of the policy interventions proposed here is exactly to enhance mobility and stimulate innovation.

9.3.3 Scenarios

By and large, there are three scenarios pertaining to what robotization may do to total employment (*also see Figure 9.2*). Firstly, there is the *end-of-work* scenario in which robots ultimately do all the work and most people have no job at all. In a structural change perspective, this means that robots and AI will become so advanced that any job is almost instantaneously taken over. This would include jobs with technological complementarities, newly created ones in emerging sectors, and even jobs in robot-making sectors. Given that robots are currently far from this level of versatility, but rather designed for specific tasks, the diffusion and adoption is expected to occur gradually. However, note that once robots start designing & making robots, development may well accelerate. Secondly, there is the *structurally* lower scenario in which robots and humans each do part of the work. It is well conceivable that people take care of inherently human tasks, while robots do the tedious or intensive work. Moreover, it may also that work hours decrease across the board. A more refined discussion on tasks and skills (left) for humans is found in section 9.2.3.

Thirdly, there is the *rebound* scenario in which robots will gradually take over tasks, possibly even rapidly, but new jobs emerge which cannot be done by robots immediately and which will employ the human workforce. In this case, the level of unemployment returns to a 'regular' rate of frictional unemployment. Also note that a structural transformation with a rise of (employment in) quaternary sectors (some of which are headed under 'spillover') contributes to a rebound. Both in the rebound and in the structurally lower scenario, education moderates the pace of technological progress. However, in the rebound scenario, people can reskill and catch up faster than technology can progress.



End-of-work: progressive substitution of capital for labor and countervailing forces are too weak to compensate for job loss.

Structurally lower: capital for labor substitution tapers off, but countervailing forces do not create enough jobs.

Rebound: whether capital for labor substitution continues (A) or tapers off (B), employment rebounds to former levels due to countervailing forces

Figure 9.2. Three scenarios on the development of employment subject to the introduction of robots (see Vermeulen et al. 2018). The continuous line is the level of employment, the dashed lines are two scenarios on the degree of robotization (or, in general: capital intensity of work). (Data visualizations by Ben Vermeulen; see also Annex 1: responsiblerobotics.eu/annex-1).

9.3.4 Education and labor mobility

For the end-of-work scenario to occur, either one of the following two conditions is to be met. Firstly, the job destroying potential of technology through substitution exceeds the job creating potential of technology (through complementarities (MacCrory et al. 2014) and other countervailing forces). Or, secondly, the rate at which humans can be reeducated and retrained for new employment is lower than the rate of technological advancement (Brynjolfsson & McAfee 2011). Moreover, whenever the mobility of workers increases, the dynamic efficiency of adjusting to shifts in labor demand also increases. Consequently, the peak in technological unemployment is also reduced. So, education is a prominent moderator of the labor economic impact of robotization and offers an instrument to policymakers.

First and foremost, education is pacing robotization itself. Robots developers of specialized components (AI, machine learning, battery technology, etc.) are required to be educated and their skills and knowledge needs to be kept up to date (e.g. by training-on-the-job, attending conferences, following micro-masters). Moreover, with the introduction of robots, task requirements in existing, applying and complementary sectors change. Consequently, adoption requires reskilling of the existing labor force.

Secondly, people, who lose their jobs, need to be retrained for other jobs. As the creation and emergence of new sectors and thereby new jobs are contingent upon innovative and entrepreneurial activities, the migration of labor from old to these sprouting sectors is to be facilitated. So, technological progress and job creation in new sectors and hence absorption of workers that became redundant in older sectors stagnate, if education institutations are unable to forsee, which skills will be required in the new economy.

Note that the gradual transition of the labor force due to workers retiring with outdated skills and influx of young workers trained in currently required skills may be too slow. As such, workers have to acquire new skills during their working life (Peters 2017) and are to be (re)trained (possibly multiple times) during their career. However, as illustrated in *10.0 Meaningful Work*, REELER research into affected stakeholders shows that some people end up in their jobs, because they only have an elementary education, are illiterate or dyslexic, or their life circumstances have restricted their choices. There may be practical obstacles for these people to engage in training or studying outside of their job. See the quotation below from REELER's empirical data:

> *Interviewer: "You don't think you could reconcile work with school?"*
>
> *Veronica: "No, because I'm living alone, I don't have anyone to help me. I live alone with my daughter and when I'm working, she's in school, when I leave work, she leaves the school, then I have to go get her and stay at home with her."*
>
> (Veronica, cleaning staff, affected stakeholder, SPECTRUS)

Considering that robots are now gradually diffusing into service sectors that offer work to people who have had limited education and have limited opportunities, the educational system may need to be revised to also offer opportunities for reskilling to these people.

9.3.5 Graduality of robotization

Regardless of whether robotization will ultimately replace most of the human labor force or not, it is expected to be a gradual process for various reasons. Firstly, sectors and occupations differ substantially in the ease with which robots can replace labor. After all, the elasticity of substitution (i.e., the degree to which factors can be substitute for one another in the production function)[11] depends on the complexity of tasks at hand, socio-technological features of the production (or service) process, etc. This in turn affects the price of the robots to develop. Given the substantial wage and robot price differentials of sectors (and occupations), firms in the various sectors will adopt robots at different points in time. Indeed, while robots are used already for decades in Fordist factories, robots are only now gradually entering services (Decker, Fischer & Ott 2017).

Secondly, firms in the robot making sectors typically first build robots to do repetitive and physically easy tasks, to be deployed in sectors in which wages are relatively high and jobs cannot be easily offshored. Only with the advancement of robotic technologies, notably electromechanical actuators, sensors, processing power, and artificial intelligence, can robots be expected to take over more complex tasks. However, whether these technologies are developed depends on the market viability and notably the wages in the apply sectors. This in turn is moderated by the labor mobility, labor competition, etc. As such, the faster robots destroy jobs, the faster developing more advanced robots becomes financially unviable.

Thirdly, robotization is by no means inevitable. Whenever labor mobility is limited and unemployment rates rise, governments may well intervene to moderate the pace, e.g. using robot taxes, wage moderation, etc.

9.4 Policy interventions

As outlined above, the progressive adoption of robots, if occurring, might have several fundamental consequences in terms of employment, income, and opportunities. However, so far, the role of governments has not been explicitly considered. Governments have several instruments at their disposal to regulate the adoption of robots and/or mitigate their impact thereof. In a report containing recommendations to the Commission on Civil Law Rules on Robotics, the Committee on Legal Affairs writes *"the development of robotics and AI may result in a large part of the work now done by humans being taken over by robots, so raising concerns about the future of employment and the viability of social security systems if the current basis of taxation is maintained, creating the potential for increased inequality in the distribution of wealth and influence"* (European Parliament 2016).

Progressive robotization may upset the labor market by challenging the sustainability of the current social safety net. The Committee recommends considering the introduction of "corporate reporting requirements on the extent and proportion of the contribution of robotics and AI to the economic results of a company for the purpose of taxation and social security contributions." This alludes to a 'robot tax'. However, the Committee continues and states that *"a general basic income should be seriously considered"*. Moreover, the Committee recommends "start monitoring job trends more closely, with a special focus on the creation and loss of jobs in the different fields/areas of qualification in order to know in which fields jobs are being created and those in which jobs are being destroyed as a result of the increased use of robots." So, there seem to be three main types of interventions: impose a tax on robots/ robotization, provide an unconditional income, and catering to the shifts in labor demand. Below the three types of policy interventions are discussed in detail (also see Vermeulen, Kesselhut, Pyka, & Saviotti 2018).

9.4.1 Robot tax

Whenever robotization eliminates more jobs than it creates structurally – directly or indirectly – it may be commendable to regulate rates of adoption. A 'robot tax' (Abbott & Bogenschneider 2018; Guerreiro, Rebelo, & Teles 2017) is a general notion concerning taxation of either the ownership of a robot or value created by (application of) a robot. There are three main ideas behind robot tax.

First and foremost, the idea is that taxation of robots is a disincentive for labor substitution. Indeed, imposing a tax, and thus making robots more expensive to buy and/or use, makes robots less attractive as a substitution for human labor, and would thus curb, mitigate, slow down, or stall robotization, albeit from the cost economic perspective described in section 9.1.1. Note that tax systems in most countries do tax labor but not robots, which contributes to the substitution of labor by robots.

Secondly, in the popular debate, the tax revenue is earmarked (hypothecated) to combat (supposedly adverse) effects of robotization by redistributing wealth, close the income gap, provide an unemployment benefit particularly for those displaced, compensate those that are directly affected, etc. (Gasteiger & Prettner 2017). An earmarked tax[12] is allocating the revenue from a single source to a single public service (generally within a multi-tax, multi-service fiscal unit). Arguably, introducing an earmarked robot tax seems impractical. Collecting taxes from the robot owners (say, for instance, manufacturing firms), on the one hand, and immediately providing particular services such as direct monetary compensation, training, etc., on the other hand, may impose a consid-

11 The notion of elasticity of substitution was originally introduced by John Hicks in 1932. It expresses the degree to which factors can be substitute for one another in the production function. Generalization of the ratio formula to multiple dimension is involved, see Blackorby & Russell (1989). Prominent evolutionary economists have criticized the notion of production functions as over-formalization, see e.g., Foster & Wild (1999) and Foster (2005).

12 A seminal, formal treatise on earmarked taxes can be found in Buchanan 1963.

erable administrative burden. Moreover, there are reasons to question the possibility of computing the optimal level of taxation,[13] the right amount of compensation, etc. Arguably, economies are rarely ever in equilibrium, and economic actors, including governments, are boundedly rational (Simon 1972), imperfect informed, struggling with combinatorial complexity, etc. Clearly, using a generic capital input tax in combination with a general unemployment benefit does not impose new, specific administrative burdens and most legal units already have public institutes in place for this (e.g. municipal employment agency).

Thirdly, the robot tax revenue may be used to (contribute to) create employment opportunities, enhance labor mobility through training and education, etc. Arguably, the upward mobility of the unemployed both between occupations within and between sectors (*see sections 7.2.3 and 7.3.4*) may be limited: these workers may have been laid off because they struggle with acquiring skills required for jobs in demand (particularly in the newly emerging sectors), may lack the aptitude, may not be motivated (e.g. close to retirement), etc. The latter topic is discussed more generally in the context of the 'dynamic efficiency' policy.

9.4.2 Universal basic income

A 'universal basic income' (or: 'unconditional basic income') is a regular income to any member of society regardless of wage, other sources of income, employment status, intentions, etc., and without further obligations. It supposedly buffers against poverty and guarantees access to resources to sustaining a certain standard of living (Colombino 2015; Parijs 1995; 2018; Parijs & Vanderborght 2017; Standing 2017). Moreover, from an innovation economic perspective, the individuals receiving universal basic income may pursue (entrepreneurial) dreams at limited risk. So, the basic income may stimulate entrepreneurial activity, innovation, and the creation of new sectors. However, there is a wide range of economic concerns about the viability of the universal basic income. Concerns covers, among others, sourcing, costs, and effects such as inflation and lower participation (*see e.g. Clark & Kavanagh 1996*), lower real income for the (voluntarily) unemployed (cf. Groot & Peeters 1997), or rather higher wages (*see e.g. Levin-Waldman, 2018*), as well as practical issues to consider (De Wispelaere & Stirton, 2012).[14]

Moreover, also from the perspective of workers, it is not necessarily desirable. Across REELER cases, affected stakeholders were asked about their perspective on universal basic income, explained to them as a governmental intervention that would keep them from falling into the poverty that might follow if they were to lose their jobs to robots. Among hotel cleaners in Portugal, what became clear is that 'avoidance of poverty' is not the only reason people go to work:

> *Interviewer: "Universal Basic Income is an unemployment subsidy. Imagine that a robot came to work in your place and you had to go home but you received lifelong unemployment subsidy."*
>
> *Frida: "But it doesn't compensate. It's not about the money."*
>
> (Frida, hotel cleaning staff, affected stakeholder in SPECTRUS)

The question of universal basic income also emerged among other affected stakeholder types in other cases. The German labor unions are generally not in favor of universal basic income; they seek to create meaningful work and workplaces for citizens that ensure them an income and a 'good life', and they fear that a universal basic income will cause greater social inequality. Another affected stakeholder, Marc, is more open to the idea, though he thinks it is doomed to fail in Germany because of a strong work ethic and identity tied to work:

> *But I do not think it will prevail here in Germany. In Germany, I would rather say that people can also distinguish themselves by their work, because they also identify strongly with the work they are doing. And accordingly, you want to be able to differ within certain salaries, like performance for money or money for performance.*
>
> (Marc, university researcher, affected stakeholder, COBOT)

Both affected stakeholders and robot developers across cases in REELER expressed that their work was important to them because of the satisfaction, pride or fulfillment it gives them.

13 For an advanced, albeit equilibrium model on the optimal taxation of robots, see: Thuemmel 2018.

14 There are concerns about sourcing, costs, and effects such as inflation and lower participation (see e.g. Clark & Kavanagh, 1996), lower real income for the (voluntarily) unemployed (cf. Groot & Peeters, 1997), or rather higher wages (see e.g. Levin-Waldman, 2018), as well as practical issues to consider (De Wispelaere & Stirton, 2012). With that, it remains to be seen whether it truly ensures a certain standard of living and safeguards demand for goods and services. There is a wide range of effects foreseen, including changes in the hours actually worked, an increase of and shift in consumption (products and services) and investments, ability to study, etc.

I mean, I think there are a lot of craftsmen who like to deliver a result, and if they can deliver a larger result per day, I think they would feel good about that. But there is also the issue of professional pride. And if we are to talk ethics, I think there are lot of craftsmen that would be affected if they are placed in the secondary position.

(Dan, development consultant, affected stakeholder in WIPER)

STORY FROM THE FIELD:
Poverty versus colleagues

Veronica is a cleaning staff in Portugal – she works 4 days a week and earns 400 EUR per month. Her boss has never made her a contract and does not want to. He pays Veronica and the other workers by the end of the day each time they clean. Veronica works 9 to 6 with a one-hour lunch, but often has to work in the lunch hour. She cleans private vacation rentals for residents who rent the houses from Veronica's boss, who is also the owner of the vacation houses. Veronica's schedule can be very tight on time because she must do everything in the house (sweep, wash, fold towels) and there are too many clients. She explained to a REELER researcher that she cannot stop for a little while even when she is very tired. After a 4-day work cycle, Veronica rest for three days. On the first day she rests the whole day because she is physically exhausted. On the second and third days, however, she wants to do something because she grows tired of being at home. She is done resting and wants to go out and do something, she explains. Despite the tough working conditions, Veronica still wants to work even if she were to get some money from a Universal Basic Income. Though she hates her boss and gets worn out from the work, what keeps her going is her colleagues. She works with three other women and a man who drives them from one area to the next where they clean a few houses. They stick together, chat in the van, and have a lot of fun even as they work.

(Based on an interview with Veronica, cleaning staff, affected stakeholder, SPECTRUS)

To preserve the meaningful work life, considerations of collegiality, identity, and other work values must accompany any serious consideration of Universal Basic Income (*see 10.0 Meaningful Work*).

9.4.3 Dynamic efficiency & innovation policy

Dynamic efficiency & innovation policy:
An economic growth policy, proposed to facilitate creation of and efficient reallocation of labor across occupations and sectors.

An alternative to providing a disincentive for and mitigating the effects of robotization is a policy intervention in the spirit of Schumpeter: to have unfettered competition that creates new technological opportunities and new labour-intensive jobs, and notably renders efficient structural change. To facilitate a quick and adequate rebound to high levels of employment without high peaks in technological unemployment, the 'dynamic efficiency' and 'labor generating ability' of an economic system is to be enhanced, notably by stimulating the emergence of new sectors (without harming existing sectors) and facilitating labor migration such that new opportunities are indeed reaped. However, also this policy instrument is not a panacea.

A necessary (but not sufficient) condition for structural change to occur is that entrepreneurial activity creates new jobs and there is sufficient upward labor migration (European Commission 2007; Forge, Blackman, Bogdanowicz, & Desruelle 2010). To make structural change sustainable in terms of high employment rate, wage development, and income equality, those becoming unemployed because of robotization, new labor market entrants, and also people planning on traversing the vacancy chain should have access to training and education. To this end, educational institutes need to keep pace with technological developments. That said, as became clear from affected stakeholder interviews, the current educational approaches may not be adequate (*see 7.0 on Learning in Practice*), considering that many people working in the service sector to be affected by robotization do not have an education to build upon or are hampered by practicalities such as being single parent.

Moreover, some argue that labor market flexibilization (i.e. making it easier to lay off workers and offer temporary contracts) increases the propensity to hire workers and thus help resolving unemployment and enhances mobility in the direction of new technological opportunities. This flexibilization requires revising institutional arrangements and labor market regulations such as dismissal protection, social security system, and education offered (Kattenbach et al. 2014).[15] However, empirical findings of Barbieri & Scherer and Eichhorst & Kaiser reveal that although flexibilization reduces unemployment, workers in many of the (new) jobs have

15 For the reference work on the varieties of capitalism approach, see: Hall & Soskice 2001.

temporary contracts with limited outlook on regular, steady employment. In fact, deregulation facilitated the replacement of secure, unionized labor with precarious, cheaper labor thus effectively harming career prospects and wage mobility (Barbieri & Scherer 2009; Eichhorst & Kaiser 2006). So, just deregulation and flexibilization of the labor market seems too inadequate and undermine social cohesion and sustainability.

At a first glance, adverse effects of robotization such as wage stagnation, inequality, and a high rate of unemployment are combatted by increasing dynamic efficiency (including labor market flexibilization) and stimulating innovation to promote creation of labor-intensive jobs in newly emerging sectors. However, the current educational system and labor market mechanisms need to be revised diligently such as not to exacerbate the (socio-)economic effects of robotization.

9.4.4 A refined look on policy interventions

The REELER agent-based computer model of the labor market (*see section 9.3.2 and Annex 1*)[16] is used to study the effects of the aforementioned three policy interventions on the intricate interplay of the labor market (in terms of employment rate, wages, labor mobility between occupations and sectors) and the product market (at which employer-firms and worker-consumers interact). Simulations reveal that particular policy interventions have different effects when there is labor surplus (high levels of unemployment) and when there is labor scarcity (high labor demand/ many vacancies).

In case of substantial labor mobility, labor surplus causes wage stagnation (and hence a drop in disposable income, decline in consumption, etc.), which invites entrepreneurial activity and thereby the creation of new sectors with new jobs that are -prior to rationalization- labor intensive. This restores high labor utilization rates and hence renewed wage competition. Robotization would exacerbate unemployment and prolong wage stagnation. In this case, it is commendable to have a policy mix with (i) robot taxation to disincentive robotization, a (ii) universal basic income to stimulate product and labor demand, and (iii) stimulation of innovative activities to create new sectors and education to enhance labor mobility and thus mop up the unemployed.

In contrast, in case of labor scarcity, possibly caused by limited labor mobility, wages escalate. This induces technological substitution/ robotization and slows down sector emergence. This then reduces wage competition and labor utilization. Here, robotization does free up labor, but, importantly, also resolves labor shortages, reduces vacancies, and softens (fierce) wage competition. In this case, a universal basic income exacerbates labor shortages, robot tax sustains fierce wage competition, and new sectors increase labor demand, such that these policy interventions are actually discommended.

This simulation model thus reveals that there may well be a basin-of-attraction for high employment levels, i.e. economic forces cause a return to that state. However, in case of labor surplus and high levels of unemployment, policy interventions do seem to bolster the 'self-correcting' mechanisms to return to those levels of employment through structural change and enhanced labor mobility. As stressed before, labor mobility is of paramount importance for efficient structural change and reducing technological unemployment peaks. Moreover, it may also equalize incomes and increases chances of positive qualitative change of task sets of individual workers.

As stressed, though, revisions of the educational system and labor market institutes and regulations are required, whereby special attention should be paid to particular predispositions of the work force.

9.5 Concluding remarks on Economics of Robotization

This chapter has provided a comprehensive introduction on the economics of robotization, including: the rationales for robotization, impacts of robotization including impact on workers and structural change, and some of the proposed or emerging policy interventions in response to robotization.

The chapter opened with a discussions of what drives firms to adopt and develop robots. Firms in mature manufacturing sectors primarily adopt robots to increase efficiency, rationalize production, save labor (or overcome labor shortages), and thus remain cost competitive. In other sectors, firms adopt robots to differentiate products and services offered, alleviate human workers of particular tasks, or meet social expectations. Robot developers seek to cater to the needs of actors in both types of sectors. On the one hand, there are (often entrepreneurial) robot developers that seek to create new applications of (new types of) robots (e.g. in healthcare) and thereby quite commonly also receive public research funding. On the other hand, there are (often more established) robot developers that seek to make robots that allow customers in the manufacturing sectors to rationalize production and lower production and labor cost (*see 2.0 Robot Beginnings* [17] for a more in-depth discussion).

Beginning with an historical overview of mechanization and automation, section 9.2 studied what might be different this time around in a discussion of the possible and actual consequences of robotization for workers. If robotization results in higher productivity, fewer workers will be needed and robotization may thus result in job loss or lower wages. Robotization might also result in qualitative change to the (set of) tasks executed by human workers. Humans might get tasks that are more challenging or complex (taken to mean "less dull"), are complementary to robots and require advanced skills, or require distinctly human qualities. In contrast, hu-

16 see responsiblerobotics.eu/annex-1

17 This chapter is only included in the online version of Perspectives on Robots responsiblerobotics.eu/perspectives-on-robots

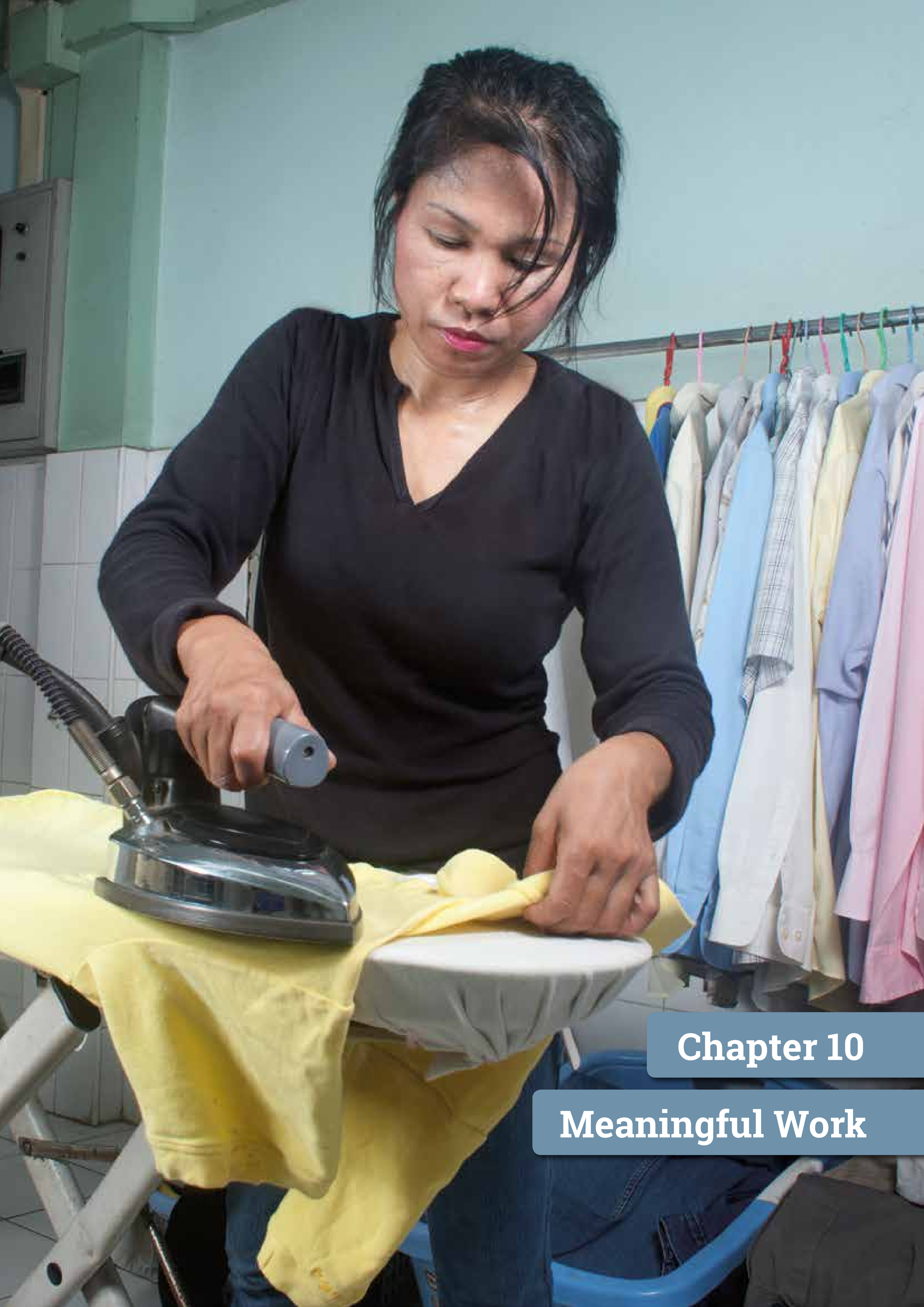
Geographical regions where robots are made may be distant from where they're applied, skewing the distribution of the benefits of economic growth and the risks of unemployment.

mans might also end up with simplified, repetitive tasks in a rationalized production process. As such, robotization is also changing the way workers experience work (*see 10.0 Meaningful Work* for a more in-depth discussion). Robotization might also affect not only the sets of tasks of human workers, but also the skills required, and demand for human workers with certain skills across a range of (existing and emerging) sectors. As such, robotization has led and may again lead to structural change in employment across sectors resulting in a need for (re)education, upskilling, and labor mobility. Moreover, robotization may even exacerbate inequality in income and labor demand between countries, e.g. by driving reshoring of production, increasing demand for workers developing robots substituting workers in another country.

In response to these expected effects of robotization on workers, skills required, and tasks performed, potential structural changes to the economy in terms of employment was explored. Returning to a historical analysis, we observe that previous technological breakthroughs have had some constructive effects, bringing about new complementary tasks, new occupations,[18] and even new sectors. So, while robotization is destroying and qualitatively changing some jobs, there are also countervailing forces that create jobs – possibly more than are being destroyed. If adoption of robots is gradual, there may be adequate time for workers to reskill or relocate. So, although robotization may cause technological unemployment, it might be temporal and the economy may rebound to high levels of employment. However, it may also be that the loss of jobs due to substitution and increasing efficiency outpaces the creation and growth of employment in new sectors. In either case, policy interventions may be required for a sustained high level of employment and to curb the widening of the income gap.

The point of this chapter is to raise awareness about the potential effects of robotization. Various policy interventions have been proposed to mitigate the potentially negative effects of robotization. This chapter addresses three main types of policy intervention: 1) a robot tax as disincentive and deceleration of robotization as well as to cover the costs of reskilling, 2) a universal basic income to stimulate consumption and thereby demand for labor, and 3) stimulating innovation and dynamic efficiency to create new jobs and enhance labor mobility. Finally, the results of REELER's labor-economic computer model simulation suggest that an integrated application of these policies, differentiated to labor economic circumstances, might be the most effective mitigation plan.

18 The "Future of Jobs 2018" report of the World Economic Forum distinguishes redundant, stable, and new 'roles'. Examples of the earlier are data entry clerks, factory workers, bank tellers, car drivers, sales agents, while examples of the latter are data scientists, digital transformation specialists, user-experience specialists, innovation professionals



Chapter 10

Meaningful Work

”

I don't know how real the story is, but our teacher told this story once. Someone developed a machine that could score pork roasts. You know, a lot of people were standing at this line and then they scored all these pork roasts. It was the same motion. It was hard on the wrist but they got a lot of money for it. That was also piecework. Then someone thought of making a machine that could score a whole pork roast all at once. You simply just put it in and then it was scored, all of the rind was scored all the way down on this, like, one and half meters of pork roast or however long that is. That machine never got running. Every time it ran, someone accidently threw something in so it broke. So, in the end, it was just placed in a corner and dropped.

(Werner, operation and production technologist, robot developer, WIPER)

◀ Cleaning staff disagree with robot makers on whether their work is menial or meaningful.

10. Meaningful Work

How the robot revolution will transform work and the worker

You will find here

- Definitions of work, labor, automation
- REELER findings of how robot makers view work and workers in a laboring society
- Theoretical overview of positive, deterministic, apprehensive, and resistant attitudes toward technologies
- New insights into work-life from a shop-floor view
- Empirical data challenging the rhetoric of relief, menial labor and efficiency
- New insights into robo-sabotage and its reasons

You will acquire

- Awareness of how robot makers envision work and workers from the perspective of relief
- Awareness of how 'relief' build on an assumption of human workers as engaging hard, repetitive and wearing labor
- Awareness of how humans at the shop-floor might find even menial work meaningful and rewarding
- Awareness that work is not just about being efficient and productive, but about identity, pride, skilfulness and fulfillment

10.1 What is the meaning of work?

What is a meaningful work life? How will automation and robots influence what is meaningful about work? In answering these questions in robot development, can we increase acceptance and avoid robots being sabotaged or abandoned?

This chapter addresses the *meaning of work*. The philosopher Hannah Arendt makes a distinction between labor and work: The former being a means unto itself – the work that all animals do to stay alive and procreate. Labor is the 'toil and trouble', which automation and robots are expected to liberate us from (Arendt 1998, 4). Work, on the other hand, Arendt describes as productive and permanent – humanity's mark in the world. The problem is, according to Arendt, that our society has become a 'laboring'-society:

"It is a society of laborers which is about to be liberated from the fetters of labor, and this society does no longer know of those other higher and more meaningful activities for the sake of which this freedom would deserve to be won." (Arendt 1998, 5)

The ethnographic studies in REELER brings us in close proximity to humans engaged in many areas of work other than engineering (cleaning, inspection & maintenance, education, transportation, logistics, production and manufacturing, agriculture, construction, healthcare, scientific research), and we have interviewed 160 workers (robot developers, researchers, teachers, labor union representatives, cleaners, farmworkers, physiotherapists, doctors, warehouse workers, factory workers, construction workers, pilots, air traffic controllers, mechanics, delivery drivers).

It is from the analysis of REELER's 11 robot cases that we come to question a self-evident assumption of labor as 'toil and trouble' from which humans are happy to be liberated. What is perceived as menial and repetitive labor by some can be seen as meaningful, creative, and productive work by others. Furthermore, REELER's cross-case analysis shows that the perception of work as laborious influences how workers themselves are perceived. In the 'laboring society', a perspective shared by many

> **Work:** *Remunerated human labor, both as a means unto itself and as a means of production.*

developers, economists, and policymakers is that relieving humans of hard labor is always a good thing. However, in our ethnographic research we also encounter other understandings of working humans on the shop-floor. These humans take pride in their work and the skills they develop (that others would label 'toil and trouble'), they enjoy working with colleagues, and having a purpose in life. Therefore, REELER's own definition of work incorporates both labor inherent and labor productive. Work may provide us with the means for meeting our most basic needs, but can also bring us recreation, socialization, skill development, pride, fulfillment, a purpose, an identity.

In this chapter, we present an analysis of our data on the laboring society. In sections 2 and 3, we present the robot makers' arguments for transforming work by relieving humans of hard labor, while making production more efficient. Whether for better or for worse, quests for automation are radically transforming work life. There is a developing shift in the roles of worker and robot, challenging the long-time assumption: "machines are tools that increase the productivity of workers. Instead, machines themselves are turning into workers, and the line between the capability of labor and capital is blurring as never before," (Ford 2015, xii). This shift is tied to how we conceptualize and value work and the worker, to political discourses (Industry 4.0, and relief of the worker, e.g.), and to how quickly robot technologies are developing. On the individual level, some work is becoming more monotonous and less social, some work is demanding new skills, and some work is being made redundant. These discussions are taken up here to provoke robot makers to challenge their own ways of thinking about workers, work, and automation, to raise awareness about workers' experiences of work and automation, and to possibly align the workers' and the robot makers' motives in future automation (*see 3.0 Collaboration in the Inner Circle*).[1] Then, in sections 4 and 5, we present research that 'gives voice' to people whose work lives will be affected and transformed by automation and robots but as end-users, directly but also distantly affected stakeholders. It is in this realm of everyday practices that the meaningful work-life is brought to the fore – and the human workers reveal themselves to be much more than replaceable parts of a machinery. Though we will also emphazise that robots can be, and have historically been, a great help and relief to humans doing hard work, REELER want to 'give voice' to those toiling in order to give a fuller picture of how robots affect work, and how the replacement debate is about more than salaries and the development of new jobs. In section 6, we consider the consequences of upholding these perceptions of work as mere labor, and the worker as a source of labor. Finally, in section 7, we explore a future of work where robotization is a part of, and not an impediment to, the meaningful work life.

1 This chapter is only included in the online version of Perspectives on Robots www.responsiblerobotics.eu

10.2. Perceptions of labor

> **Automation:**
> *The mechanization of human labor, both inherent and productive*

In this section, we address the role of the robot makers' perceptions of labor in relation to **automation** and some of its negative effects – replacement chief among them. REELER's definition of automation is the robotization of human labor, both inherent and productive. Automation of labor is achieved at different levels, covering complex work tasks (e.g., knitting or circuit board assembly), down to the simplest labor tasks (e.g., opening doors). *Full automation* implies that the human is entirely displaced from the work, while *partial automation* keeps some humans in the workflow, where the robot performs particular tasks. Historically, both partial and full automation have transformed work life, sometimes significantly for the better and sometimes to the detriment of particular persons.

Many robot developer participants in REELER's research refute or balance issues of replacement and other negative effects of robotization with the positive effects or goals of automation. In particular, many members of the robotics community are caught up in a particular rhetoric around employment: Robots create more jobs than they replace.

> *Then there are things like, what people talk about: 'Are the robots going to take our jobs?' If you look at what happens, then it just so happens that robots also contribute to the productivity, and productivity is better earnings, and better earnings is better competitive power. So, if you look at what happens in, well, in the short view, a year or two, then it can mean in some companies that you have to fire some people. But, most often, you also increase the company's earnings and the company grows on that foundation, so you, all in all, in reality, could increase the number of employees in that company.*
>
> (Valdemar, engineer and CEO, robot developer, WIPER)

Indeed, robotization is likely to eliminate particular occupations or sectors while opening for brand new or transformed sectors (*see 9.0 Economics of Robotization*). But, what happens to workers in these transitions? Another primary justification provided for automation is *relief*, which we challenge by giving voice to the workers expected to be relieved. We have identified in REELER's data two distinct ways of thinking about the human that permeate these conversations about relief and replacement: the human worker as a labor source, and the worker as a whole person. These perspectives bring forth particular perceptions of the good worker and desired qualities in a robot, and challenge commonly held notions of menial and meaningful work.

Most robot developers interviewed in REELER do not feel that their own work could be replaced by a robot or AI, but can easily imagine a robot 'relieving' manual laborers of burdensome tasks.

The perception of the human as a labor source seem to come with deterministic perspectives on automation. Automation decisions are often built around a particular way of thinking and talking about the human worker as a commodity, in terms of 'productivity', 'expenses', 'efficiency', and even 'optimization' and 'standardization. This discourse is not just among the people who make robots, but also among REELER's affected stakeholders. When the human is equated with the machine as a source of labor, reduced in complexity and measured as means of production, it becomes easy to imagine a machine replacing the human.

From this line of thinking comes an attitude of **technological determinism**, where the reasons for automation are so self-evident that technological displacement becomes inevitable. Many of REELER's participants had a helpless or passive orientation toward robotization, their arguments often resting on historical precedence: Technologies have been evolving alongside humans for centuries, and because advanced tool-making is a cornerstone of human exceptionalism (Idhe & Malafouris 2019), technological change is thus an unstoppable force.

Technological determinism: *The attitude that automation is inevitable, or, that the reasons for automation are self-evident; technological progress as an unstoppable force.*

Surely there are hazards, but I am going to make use of the slogan that we have employed many times: We live in the twenty-first century, technology surrounds us either side; we cannot avoid it.

(Erwin, university psychologist, robot maker, ATOM)

This argument assumes technological displacement as a part of the natural order. Sometimes coupled to the passive attitude of technological determinism is the more active or biased attitude **technochauvinism**, where technology is assumed superior to all other potential solutions or sources of labor. These biases are intertwined with the depictions of robots and humans we encounter in news and popular media (*see 8.0 Imaginaries*).

Technochauvinism: *The assumption that technology is superior to all other potential solutions, or, in automation, to all other sources of labor.*

In REELER's case material these discussions are tied to the *purpose* of robots and what it means to people to have a job. On the one hand, some point out that we have seen in agriculture since 1900s that robots really help people free from the toil of hard work that breaks their bodies and wears them down. The robot type that replaces people can have a positive effect on affected stakeholders, if they can subsequently create or find new and better jobs. The robot that help workers or free workers to find better jobs will have a positive effect, as the robot is a genuine help for them in their work and does not affect their pleasure and identity in work in a negative way. However, robots can also have a negative effect on affected stakeholders' work life, if humans are replaced altogether by robots – and do *not* find new satisfactory work. In this case, they not only lose a salary (which some want to remedy with Universal Basic Income), they also lose identity, human contact in the shape of colleagues, pride in skills, etc. However, this is only apparent if one views humans as more than replaceable parts in a machinery.

Throughout REELER's data, both robot developers and robot buyers frequently compare robots to human workers as labor sources – often preferring the machine. Even the workers themselves can see themselves as a less attractive labor force compared to robots. When confronted with an imaginary of the robot laborer which does not get sick, need coffee or cigarette breaks, and which works 24 hours a day (including Sundays), the replacement of the human worker can seem very appealing:

[Robots] don't have hangovers on a Monday morning, they don't ring in sick.

(Brian, wholesale store owner, affected stakeholder, WAREHOUSE)

They're not standing there having a cup of tea and a fag, are they?

(Benny, mechanic at family-owned garage, affected stakeholder, HERBIE)

This is especially the case for small and medium size enterprises (SMEs) where fluctuations in human labor or in production output are much more difficult to tolerate or accommodate:

You always need to think like that, what would happen, if someone gets sick, while at the same time another gives notice, and one then would be alone. Then that person has to do the work of three, the whole manufacturing would break down.

(Karl, SME owner, affected stakeholder, COBOT)

Technochauvinistic attitudes lead to the application of technologies to solve, for instance, socio-political problems like labor challenges or environmental problems, like developing robotic pollinators in response to declining bee populations (Potts et al. 2018). These perspectives, which measure humans against robots as labor commodities and frame the automation of human labor as self-evident, inevitable, most effective, and natural, leave little room for exploring non-technological solutions to human problems. Of course, there are other viewpoints that are not so deterministic in our data material.

Not everyone is convinced that human workers can be fully substituted by robots and some are also sceptical towards the idea. Most robot developers interviewed in REELER, for instance, did not feel that their own work could be replaced by a robot or AI. However, they could envision robots taking over some of their manual labor tasks.

Really for my work I think it's not a problem because my work requires to use the mind, about the design, but I think for a lot of people this transformation will be not simple. It's like all the revolutions, like the industrial revolution, or the internet revolution. All the revolutions have a specific problem for a certain type of people. I think in this case it's the same, the same. For me it's not a problem, but maybe for the person that is in a factory, just putting a screw, a robot is a competitor really and a big problem for his income, I think.

(Hugo, mechanical engineer, robot developer, HERBIE)

Among the manual workers (i.e. affected stakeholders in REELER) some did fear that robots would take over their jobs, even if they would not perform as well as the human: *"Robots can't wash a table."* (Elif, hospital cleaning staff, affected stakeholder, SPECTRUS).

A number of participants interviewed by REELER researchers described robots as slower or less effective, more expensive, less flexible, and less intuitive than human workers, but others emphasize they are too fast to do a proper job. At small businesses (and we have only visited a few) they also see a problem in relying on robots actually being the better choice. SMEs must be more flexible for small-batch manufacturing, and that robots are still too costly to regularly reprogram and re-integrate into production processes.

The product the robot is making should cost as little as possible. We are the zero-cost-faction here. Yes, it should come at no cost. Every price that you submit already is one too high. Definitely, and you need a price break-down; do I use a worker, who earns ten euros, who does the job, or do I choose a robot, which, I don´t know, in principle, costs 10,000 Euros, and which needs to be programmed by an extremely expensive man. But why should I delegate work to a robot, if it is done after three hours, and after those three hours, I have to reprogram all-new?

(Karl, SME owner, affected stakeholder, COBOT)

Thus, a particular barrier to full automation is the perceived and real immaturity of existing robotic technologies, and a skepticism toward the ability of emerging technologies to match the qualities of the manual worker. When participants looked beyond the worker's value as a source of labor and instead thought of their whole value, the human worker was not so easily automated, particularly in terms of social skills (in teaching, e.g.), complex work activities (complicated window installations, e.g.), or decision-making (in rehabilitation, e.g.). Wherever a task or job is too complex (picking tomatoes in a hilly area), the environment is too unpredictable (a construction site), or the process is too reliant on distinctly human skills (a classroom) for full automation, there is still the option of partial automation or task automation. Indeed, there is increasing emphasis on task (not job) replacement in economic predictions (Brynjolfsson and MacAfee 2011; Brynjolfsson and Mitchell 2017). Yet, even task replacement is not that uncomplicated (and not without consequences; *see section 10.5 on transformation of work*).

10.2.1 Partial automation or replacement

Partial automation often comes in the form of assistive and labor-saving technologies. These machines can replace or support particular tasks, and often do not eliminate a person's job entirely. Robot makers tend to describe these robots as helpful or collaborative tools that save the worker from arduous labor, and they tend to explain away the instances where assistive automation also results in a reduced need for human workers.

STORY FROM THE FIELD:

Gradual reduction of manual labor(ers)

Many robot makers refer to developments in agriculture as analogous to modern robot developments; a story of machines with a long history of helping to relieve humans of labor. We meet Theo, an university researcher who gives us one example from agriculture.

"And it starts already there with the plow. It's a very simple thing to automate your hand tool with a tractor and so forth. And this process is going on for a long period already, I think. And, so robotic things are now introduced in the sense of precision agriculture, so that they can precisely manipulate actions in the field on a plant level [individually, as opposed to a whole crop adjustment]."

Measures of partial automation do not mean a one-to-one substitution of human labor with machine labor, but they eliminate particular manual tasks that accumulate to a consolidation of manual labor and the gradual displacement of workers, as one farm worker, Omar, explains with the recent introduction of a tractor.

"Before, where I used to work, there were more people. But last year they bought a tractor. This tractor took people's jobs. It takes people's jobs away, because the work that the tractor does now, I am the only one who does it. Before, we had three more people to pick up the tomatoes. The people had a cart and could move them by pushing the cart. But now everything is taken in less than half an hour into the storage room. The work people used to do in a day, I do in less than half an hour. This tractor, yeah, some technologies like this one, just a little tractor with the lifting tool, allows the grower to eliminate two jobs and he is now doing the job of those two people in a couple of hours -- and that's very useful. It's easier for them."

Undoubtedly, the machine relieved the worker of some labor (pushing carts), but Omar also took on new tasks such as driving the tractor. His experience of work was also significantly altered while three of his co-workers were displaced entirely.

(Based on interviews with Theo, university researcher, robot developer, and Omar, farm worker, distantly affected stakeholder, SANDY)

What comes across in REELER's analysis is that robot developers' and robot buyers primarily think of reduction in the amount (and costs) of labor as an inherent relief, but this is not necessarily a relief to the worker. Furthermore, technologies often relieve workers of more than tasking physical work by eroding the overall amount or sum total of manual labor in the workplace. Automation historian David Noble (1993) explains the unspoken ambiguity of 'labor-saving' machines: "In short, labor-saving technologies have not been used to save worker's labor—meaning physical and mental effort, but rather to save capital labor—meaning workers (and wages)." (ibid, p. 87) This conflation of both *work* and *worker* as labor is made possible by reducing humans to their productivity.

The point we want to make here is that if robot developers and owners of enterprises see humans as labor sources comparable to machines – and therefore replaceable – they overlook a key REELER finding: There is more to work than the labor that can be performed by a robot. Work can also be meaningful for humans – something we suppose is not the case for robots.

Not surprisingly, replacement due to automation is one of the most prevalent fears in REELER's data. One industrial designer argues that robots will replace most people in the workforce and he has concerns about his own role in creating robots that replace workers:

> *It's very difficult to work with robots, because the robots will take most people's jobs. It has very serious implications that these robots are somehow taking the place of humans in the workplace. I'm an industrial designer so I don't necessarily have to work with robots. My colleagues are roboticists, so that's the only thing they are working with. Is it fine to design things that will take people's jobs away? It's very disconcerting how fast the robots will take people's jobs and how little they cannot do. It's a matter of a few years and a lot of money and then very few people will have work – especially construction, or industry, or cleaning. So yeah, it's something that I really think about a lot.*
>
> (Oswaldo, industrial designer, robot developer, SPECTRUS)

A common argument in robotics is that robots create more jobs than they destroy, but the problem is that the same type of jobs are not necessarily created, and those persons whose jobs are taken do not necessarily possess the skills or aptitude for taking the new type of jobs (*see 7.0 Learning in Practice*).

> *The bricklayer robots, you know them, right? Yeah. They are good for those who know how to adapt, right? So, there's this thing about being ready to embrace changes. Uh, and good for those people who know how to do other things than just laying bricks. But those who don't know how to do anything else than laying bricks, they will somehow end up as the losers in all of this.*
>
> (Jens, CEO at technical equipment rental business, affected stakeholder, WIPER)

While on a large-scale, replacement may not cause persistent mass unemployment (*see 9.0 Economics of Robotization*), some people may lose their jobs or some aspects of their work due to automation. When relief is offered as justification for these effects on workers, it is important to understand whether relief is real, or just rhetoric.

10.3. Robot makers' perceptions of relief

The robot makers in our REELER data are in general very concerned with 'doing good' (*as described in 4.0 Ethics Beyond Safety*), particularly when making robots for humans' work lives. They want to relieve humans of tedious work and heavy lifts. However, REELER research indicate they may build their conception of the *'good work life'* on assumptions which are not the same as those shared by users and affected stakeholders. Relief is, in robotics, the central notion of doing good, but sometimes it becomes what we call a 'shadow' motivation. A lot of the rhetoric around automation has to do with relieving the worker. Yet, instead of really putting themselves in the workers' place, what drives the development of robots and automation may be an interest in the machines themselves – and the relief is presented after the fact as a post-hoc motive. In REELER, we see that though robots can relieve workers, the whole notion of relief – i.e. who is relieved of what, and when it is relief – is much more complex. Sometimes this is a relief of certain aspects of the worker's labor, particular tasks, or of the job entirely. Yet, it may also relieve them of meaning in their work, when it deprives them of their pride, identity, collegiality, human connection (*see section 10.4*).

Automation decisions are sometimes tied to imaginaries around work (and the future of work). How we perceive relief depends on the type of labor we value. Many of REELER's participants anticipated full automation of certain sectors at some point in the near future – cars, chief among them.

> *Certainly deliveries, delivering goods (…) some emergency services, perhaps (…). So, the people who actually drive for a living are going to be the worst affected because you wouldn't need them. Like driverless lorries – my mate, Scot, he's a lorry driver – if you've got three driverless lorries, all of a sudden, you've got three lorry drivers that are out of work. So that's who it will affect. But would it speed things up? Don't know.*
>
> (Benny, mechanic at family-owned garage, affected stakeholder, HERBIE)

Others felt that certain jobs or labor classes were at greatest risk for technological displacement (i.e., 'low-skilled' workers) (Ford 2015).

Well I suppose they think, okay it's going to put these lower skilled people out of work, but then if you're thinking like me, it's going to also create more jobs for the high skilled, but I still don't think – okay maybe they think on the periphery that it's going to create more jobs than lose more jobs, but do they care? I don't think so, because at the end of the day they're probably in it for themselves and they're creating this new ideology.

(Rohit, car salesman, affected stakeholder, HERBIE)

On the other hand, the issue of 'skill shortages' arose, where skilled labor is harder to come by, sometimes due to negative attitudes toward trade or craft work.

It [skill-shortage] won´t be in the future, it´s already happening now. I'd say, full employment, everyone's dream, is, in my view, the greatest economic loss that could happen. Because, what happens? You can´t get any skilled worker anymore. Already today, I can´t find any unskilled workers anymore. We do have an advantage, actually, the number of skilled workers that we need isn´t that high. We have a lot, where we can deploy many workers, who, I´d say, do subtasks and menial tasks. In the lot, it´s not like the robot could take over. Now, we have five-six asylum seekers. We have three-four Spaniards, who do a good job, since one skilled worker adjusts three machines. And there are three unskilled workers, and after three hours, they're done. Then, he readjusts the machines. Then he does his job. But even those unskilled workers are more and more difficult to find.

(Karl, SME owner, affected stakeholder, COBOT)

Robot makers have their own role to play in reproducing perceptions of manual work as undesirable; mundane, arduous, and repetitive – *something one needs relief from*. Relief rhetoric builds on assumptions (often explicitly stated) that manual labor is simple, monotonous, repetitive, low-skill, menial, or otherwise undesirable.

We want to help people to spend less time on boring and repetitive work.

(Alph, robotics start-up founder & CEO, Robot developer, WAREHOUSE)

Why do we have to continue to perform heavy repetitive task, why do we have to consume our time for stupid tasks?!... [The human worker] just has to delegate some repetitive tasks to the robot.

Interviewer: And do you use robots on your own, in your life?

No. Maybe because I see too much of the technology, including the working. And I prefer to use the manual stuff."

(Alessio, robotics start-up founder, robot developer, COOP)

While some of these claims may be true some of the time, the normative approaches to relief ignore the real experience of workers. Further, REELER's data challenge relief as a primary motivation for automation – second to efficiency, which is tied to the driving motivation of most work today: money (*see 2.0 Collaboration in the Inner Circle*).

Sometimes, new technologies or new applications of existing technologies actually do provide some form of relief for workers, often involving physically challenging or even dangerous tasks. However, promised relief from one poor working condition (back pain from heavy lifting, e.g.) might also be extended as justification for assistive automation, even when such an intervention introduces a number of new negative consequences for workers (transitioning from a lift team to working alone with an assistive device. *See section 10.4* for more concrete examples of how robotization changes work). Further, relief can be put forth as a post-hoc motive.

Many technological aids, for heavy lifting or strenuous work tasks, have been developed for construction work. However, construction companies do not always make use of such devices. The use of robotics is at the end of the day most often driven by economics, and not just benevolent motives.

> *So, local, unionized workmen, they have to get paid more than Romanian workmen. Therefore, those people who employ the foreign men, they probably don't really care about using technological aids because then they're just eight people carrying these things and that's it. It's the same hourly rate as the local bricklayer. The incentive for using technological aids is just less depending on how low your hourly wage is.*
>
> (Viggo, worksite inspector, affected stakeholder, WIPER)

> *All ideas for the technological aids that have been developed in the field of carpentry, they come from when [we] started to issue commands about the ergonomics on the construction sites. The industry was forced to find solutions. Because one thing is that you can try to get it done because of people's good intentions and their good will and all those lovely things, but if you suddenly start getting warnings and commands and maybe fines and stuff, --like, most companies want to avoid that, right?*
>
> (Viggo, worksite inspector, affected stakeholder, WIPER)

Often, companies have no interest in protecting the health of the workers, unless they are pressured by regulatory agencies.

STORY FROM THE FIELD:

Relief as a shadow motivation

In one particular case, construction workers had been injuring their backs for many years, and these injuries were tolerated by both the workers and the company, until the company faced heavy fines for work health & safety violations and was given a command to mitigate the risks by a worksite inspector. The construction company helped to develop a robotic device to assist construction workers with the regulated heavy-lifting tasks.

Like Alexander, who is a university robotics researcher, many robot makers cite relief for workers as the motivation or purpose for developing robotic devices:

"If you look at the fact that they instead [without assistive robotics] have to stop when they're, yeah, 50 or 40 years old, then I think it makes up for it, yes. They know they will wear themselves out."

But efficiency often seems to take priority among the motives, and Alexander continues:

"Well it's supposed to make it faster. You cut away one of the workers, and the time from when you pick up the door till it's erected is also shortened. (…) It is a matter of a business case. It also has to do with the fact that robots can do some of the tiresome work for us."

Likewise, Liva, a production technologist from the construction company and customer that defined the need for the robot, acknowledges the motive to increase efficiency (i.e., replace human laborers), but justifies the automation decision because it saves the workers from injury:

"I remember I went to visit [a parts and equipment manufacturer] during my studies to see their really nice robot, which could handle so and so many pipes every second and had replaced 200 people or something like that, right? The thing about efficiency happening at the expense of 200 jobs. And which effect that has in the end. And I think this robot is different in that respect, because these construction workers, you know, these materials weigh about 90-110 kilos, that's standard, and these construction workers are worn out after two-three years, so of course the robot can go in and replace two or three workers, but it also prevents them from breaking their backs, so that's a bit different," Liva says.

(Based on interviews with Alexander, university robotics researcher, robot maker, and Liva, production technologist, robot developer, WIPER)

This, a posteriori ethical justification of automation decisions, is what Luciano Floridi calls 'ethics shopping' (2019, 186). Relief is sometimes used in a similar way – as shadow motivation. The primary motivation is efficiency or increased productivity, but relief is more palatable and is offered as an appeasement for job or task replacement.

These communities and teams and the thing about also going to work because you are happy with your colleagues and things like that, clearly that is eh. On all those parameters, the robots probably do not score high. No. But, that is part of what we have to figure out along the way, how we can incorporate that into our method of working. It is not a good thing that these workers have a bad back as 35-year-olds.

(Villads, CEO of robotics company, robot maker, WIPER)

Robotization can transform a person's experience of work when it interrupts co-operation and socialization with colleagues or results in the loss of a coworker.

Though we only have a few cases to draw on, it is prominent in these cases that when machine labor is found to be no more efficient or profitable than human labor, relief is *not* the driving motivation; the mission of relief is not enough to carry a project forward. As one participant said:

Interviewer: "So, it takes more time for an assembler to install the material when they use the robot. What do you think when I tell you that?"

Jens: "I think uh that it's a sinking ship. I think that if it takes more time, then why put money into it? So, then it would have to be some kind of Florence Nightingale because we wanted to make sure that we never put more than 4 kg on someone's spine, even though you are allowed to put 20 kg on it. It's not going to happen. No, no. No one is going to be the frontrunners and say, right, we want to be an entrepreneur or a company that a responsible entrepreneur isn't a philanthropist. That's in another forum."

(Jens, CEO at technical equipment rental business, affected stakeholder, WIPER)

This is not to say that robot makers do not care about doing good in the world. In fact, most of the developers REELER interview express genuine interest in improving life, work, or society with their technologies.

The robot does not replace the human but replaces the evaluation of the human --which is a different thing. It does not do the human's job. It helps the human to do his job.

(Giovanni, metro company, head of unit and application expert, robot maker, OTTO)

The majority of the robot developers interviewed by REELER express sentiments in line with the quotation above. They build robots to help people in their work by handling the repetitive, dangerous or work-unrelated tasks that take up part of a work day, such as lifting heavy objects, driving wares around in a warehouse or filling out paperwork. The intention is that robots create better, more fulfilling jobs (even if sometimes eliminating other jobs).

Central to this argument are perceptions of relief: What constitutes help? Who is in need of help? How best to provide it? In practice, this is rarely done by approaching end-users directly, to inquire about what they think would be helpful in their day-to-day work lives. Instead, such perceptions are developed in the inner circles of robotics, where intermediaries function as spokespersons for users (*see the Human Proximity Model in 1.0 Introduction*). Even when robots are designed specifically to alleviate end-users' burdens, intermediaries, rather than the end-users, are consulted. This means the robots may fail to address the problems they set out to solve. In some cases, robot makers and end-users disagree about what constitutes help. For instance, robots built with the purpose of reducing or eliminating routine tasks, sometimes fail to consider that end-users might take great pleasure in this type of work.

The point here is not to diminish the good work that robot makers do, but to acknowledge that doing good may not be the driving motivation, and to suggest that closer proximity with those they aim to help may result in more concordant experiences of relief.

10.4. Workers' perceptions of work

When we look into REELER's data for the affected stakeholders' perceptions of work, we find clashes where what robot makers perceive as tedious, some workers perceive as meaningful. Some workers are skeptical of relief, while others are simply content with the type of work they do and the conditions under which they do it. The need for relief is not simply a personal matter, it is cultural and situated. Take, for example, cleaners. REELER interviewed women cleaning hospitals in Denmark and women cleaning hotels in Portugal. In the Danish hospitals, working conditions and pay are reasonable. The hospital cleaners and their manager (who also began as a cleaner) did not talk about needing relief, but instead talked about how much they enjoyed their work – including the physical aspects.

> *So, I actually came out here and started to clean at the hospital while I was still studying, and the year before I finished studying, they asked me, if I would be interested in being part of the team. I said: "Okay, I can try it." I just kind of found out that I loved it! Well, I really like my work out here. I always liked the physical part of the work out here.*
>
> (Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

The workers' satisfaction in their work relates to government and managerial policies/practices. In fact, one of the Danish hospital cleaners came to a point in her life where she could no longer fulfill some of the more physically challenging tasks, such as cleaning windows. Rather than retire her from the workforce, the municipality paid for her to have an assistant to perform those tasks that she was no longer able to perform. This social welfare support provided the relief that automation might have provided, and did so without depriving the worker of purpose at work, socialization, or her role in her community. Improved working conditions, including better management, effective tools for cleaning, more autonomy and respect, better pay and working hours, had an impact on how work was experienced by the workers.

> *I have been here for 13 years – as my other home. I have gotten very used to it, and I am very fond of my work. Because we are many people here, and we have the perfect manager who understands us, and I am very fond of the ward, and the nurses and everything. And the working hours I am very content with. And in terms of ergonomics, it is also very nice. We aren't straining our bodies, if we use the right cleaning appliances and cleaning methods; if we know it, then we are not ruining our bodies in that way. So, I am very fond of it all. We can ask for days off, and almost every time, we are given the off days that we have asked for. Yes. I am fond of it all.*
>
> (Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

Besides an income, the service workers are seeking a meaningful work life, a job that provides them with:

> - *Accomplishment: work that you finish every day.*
> - *Human connection: workers are very satisfied because they get a lot of compliments, they feel, when they talk to the patients, they can feel that they also make a difference for them, actually.*
> - *A good team: [a] pretty open-minded and also interesting, interested [team].*
> - *Respect: What I think, however, and that's really important that I say it. It's very hard to get respect for this type of work, because it's something that everybody thinks they know about, because they clean at home.*
>
> (Inge, hospital cleaning department manager, affected stakeholder, SPECTRUS)

Women cleaning hotels in Portugal do not express similar experiences with their work conditions when interviewed by REELER researchers. Their work hours were long, their tasks demanding, their pay poor, and did not receive the same social supports while working under tougher conditions. These social conditions contributed to their need or desire for relief.

> *If the company buys a robot to assist my work, and if they see that they spend less money with the working robot, they will put me on the street and put the robot to do the ironing. I will be without a job, that's what I think. That's why I say that I do not want it to do the ironing, I want it to fold the towels. I like ironing. I need to work.*
>
> (Ninea, hotel cleaning staff, affected stakeholder, SPECTRUS)

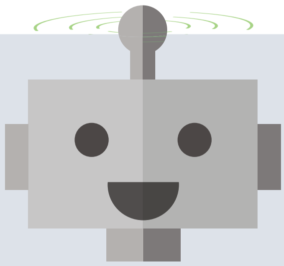
However, as seen in these statements, the cleaners made it clear that it was aspects of the job, but not the job itself, that they would like relieved. As difficult as the work was in Portugal, the workers generally did not want to give up work itself, even for a basic income.

Funnily enough, the robot developers (mostly male) in REELER's data were especially concerned with automating housework and laundry – 'invisible labor' traditionally more often done by women, but more recently increasingly shared with men (Hatton 2017).

> *It could do a lot more jobs around the house. I can see them doing the ironing, menial chores around the house. If you could make one that does the ironing yeah, we'd all have one of them. Yeah, I think just the stuff that people don't enjoy doing, like housework, which is now degrading to the robot. It's probably far cleverer than I'll ever be, but it would certainly take the pain out of the weekly chores of hoovering, cleaning, washing, ironing, kicking the cat out at two in the morning, all those kinds of things so you can actually get on and enjoy your weekend for what weekends are meant to be.*
>
> (Jerry, mechanic at family-owned garage, affected stakeholder, HERBIE)

Here, we can see how ironing has become a chief example of menial, tedious work – undesirable. Yet, our affected stakeholders counter these claims, finding meaning in the work that they do and performing complex and highly skilled work that robots still struggle to emulate.

> *I do not think that [universal basic income] will prevail here in Germany. In Germany, I would rather say people can also distinguish themselves by their work, because they also identify strongly with the work they are doing. And accordingly, you want to be able to differ within certain salaries, like performance for money or money for performance.*
>
> (Marc, university researcher, affected stakeholder, COBOT)



STORY FROM THE FIELD:

Meaningful vs. menial work (ironing)

Paloma lives in Portugal and irons for a living. Though ironing is often looked down upon as tedious and one of the many chores many people would like a robot to do for them, Paloma really enjoys ironing; so much she wouldn't even give it up for a guaranteed basic income.

"*Look I will be honest, I like the work that I am doing! I am an ironer [person who irons clothes] and I actually like it. I love my work; therefore, I don't think I would want anything else.*" Paloma started working at the hotel as a maid fixing the rooms, but *"I didn't like it, what I liked was to iron"*. Nine years ago, she started working in the hotel laundry where she runs the *"washing machines, I dry clothes, fold, iron, fold towels. I iron the sheets, the towels, cushion covers, I do a lot of things"*.

To some, Paloma's work sounds repetitive or boring, but Paloma has developed particular routines and practices through experience that makes work social and complex. Sometimes another girl is helping out in the laundry.

"*Sometimes, she helps me. She folds the towels, and only I iron them. I put it on the washing machine and afterwards, I take everything and put it to hang over the washing machine. For example, the cushion cover I don't like to dry in the dryer, that's why I dry it naturally. So, I leave it for today to dry, and iron it tomorrow. What I dry in the dryer is the sheets, covers and towels. The towels I only dry in the afternoon, because at the end of the day, I prefer to handle the drying of the sheets and the linens to be able to always guarantee me something to do at work. Later in the afternoon, I dry the towels, and if I have time, I leave at 16h30, if there is time, I fold it, if not she helps or I leave it for tomorrow and do it the next day.*"

A new robot company is eager to automate the work in the laundry, particularly the ironing, which is typically an unpopular task. The robot company presents their idea to the hotel staff, including Paloma, who responds:

"*I would like to have a robot in the laundry but I wouldn't like it to iron. I will iron because I like it, I don't like folding towels though. You cannot imagine the quantity of towels that has to be ironed and folded! When the house is full, I can't even breathe! 100, 200, 300, 400 towels. That's a lot of towels.*"

This story from the field serves to illustrate that normative thinking about work and labor may lead to undervaluing certain types of work, denying the skill, complexity, and meaning involved in even the most 'menial' work one can envision.

(Based on an interview with Paloma, cleaning staff, affected stakeholder, SPECTRUS)

REELER has looked into industrial, farming and construction robotics, where one may expect to find a range of repetitive tasks; however, many of the interviewed affected stakeholders find their work to be meaningful, enjoyable, and valuable. This goes against the rhetoric around automation as a relief to the manual. It is not necessarily the labor that burdens the worker, but the circumstances around the work itself – which suggests that social interventions, rather than automation, may be the solution in some cases.

Relief and arduous labor are thus relative notions, because for humans all types of work can be meaningful, and it matters who is being relieved of what and by what means. Normative notions of good work mask the human talent for finding meaning in all types of work. The following section addresses what happens to some of the values that bring work its meaning, when work is automated.

10.5. How robotization transforms work

Even when relief is genuine, partial replacement affects work and workers. A common phrase in REELER's case on industrial robots is *"Robots as the destruction of jobs"*, referring not just to a loss of jobs, but also a destruction of the nature of work humans do. The **transformation of work** may alter existing roles.

> **Transformation of work:** *The experienced changes to work and workers as a result of automation and digitalization.*

> *In any field, a human is not replaced by a robot. It's the role of the person that's changed. If a robot makes a part of your job, you may do better at other things. But it's not a substitution, for sure. If there is a substitution, probably it's because it's some dangerous field, where it's better that it's a machine and not a person.*
>
> (Angus, CEO of robotics company, robot developer, REGAIN)

Through extensive ethnographic research, REELER has gotten close to workers' everyday experiences to find what it is that makes their work meaningful. We find that transformation of work by robotization not only affects the targeted task, but also a range of aspects related to work.

Collegiality is a value tied to one's identity and role within a **community of practice** (*see 7.0 Learning in Practice*). Colleagues bring to work a sharing of experience, expertise, commiseration, history. Colleagues are particularly important to manual labor which often requires the close cooperation of a team or a pair because of the sheer physicality of manual labor. Two construction site workers might share the burden of lifting and positioning a door. Two cleaners might help with each other's tasks to finish a day of cleaning. Teams of farmworkers typically walk parallel down rows to harvest fruit or systematically prune the 'suckers' from an orchard's trees.

In one of REELER's cases, we meet a number of hotel cleaning staff members (all women) who explain how they work in pairs. One woman would, for instance, wash and iron towels for the bathrooms and another woman would fold them. The women help each other and build systems of skilled practice together. To give an example, one woman cleans kitchen tables before the next vacuum cleans underneath them. If she is late, the woman with the vacuum cleaner does other tasks until the tables have been cleaned and she can vacuum clean under the kitchen table. The cleaning staff have a very established and personalized system, particular to them, but inclusive and dependent upon collegial relations. Her system is also highly dynamic – flexibly incorporating her colleague when necessary or desirable. Robots are not especially flexible. Moreover, the loss of a colleague would entail more than a change in work processes, but a disruption of the social life in the workplace.

> *Because it is not that when we borrow the machine from each other, we ask the machine: 'Have you had a nice weekend?' 'Well, have you had a nice holiday?' 'Where were you?' 'Have you had your break?'. It actually means a lot at work to talk to one another, because sometimes one can share something with one another, then you get peace of mind. It might be that they have some ideas, that they comfort you, or they have some experience. But with robots, no. There are no persons to talk to, and one shuts oneself entirely off. One can no longer find solutions to problems, so, it becomes very, very difficult.*
>
> (Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

Similarly, one leader of a construction robot project recognizes that construction work is social, not solitary, work. It may be that not only does the robot subtract an existing human-human social dynamic, but it might add a new human-robot social dynamic (for better or for worse).

Interviewer: "What about the fact that he's going to be working alone now? Could that get boring?"

Villads: "Yes, of course it could. I suppose it could. Because right now they are two or three people working together in that porta cabin. I mean, there are obviously other people on the construction site. But I think, yeah it probably would, but I don't know if that's a problem."

(Villads, CEO of robotics company, robot maker, WIPER)

The emergence of 'collaborative robots' has even come with promises of new robot colleagues, however, REELER researchers remain skeptical of robots' ability to interact, socialize, or collaborate with the same quality and at the same level as a human colleague.

The previous examples demonstrate social aspects of work, and how human contact at work is part of the sense of collegiality and community. Loss of human connection is one fear that has already been realized with the replacement of one's colleagues. Manual work is often social, and communication with each other is an important aspect of the job – one that workers feel automation (even partial or assistive automation) may threaten.

I smile and greet the patients, when I start, and also smile.The people there are in a lot of pain and many of them are young, not very old, and they are in need of a smiling face. And I will help them if they ask me for a cup of coffee or a glass of water. So that I do as well, without doubt. And I don't disturb them if they are sleeping or relaxing. I always ask them if I should close the door, or if it is okay that I come in and clean.

(Elif, hospital cleaning staff, affected stakeholder, SPECTRUS)

In service work, it is often the human connection with e.g. patients or clients that is important to the workers. Service workers tend to place a high value on the service they provide, and the benefit for themselves, when they interact with the people they serve, which ties into their professional pride and identity.

Pride in work is a value tied to learning and identity. Many workers express pride with regard to the skills they have developed in their work. They may have a particular technique for installing doors that they have learned from hands-on experience. Or they may be more effective in harvesting fruit or cleaning the bed handles in a hospital, because of their contextual knowledge of the work task. Or, they may take pride in the care and precision they put into their ironing for clients in service work. When machines are inserted into work processes, some level of control over this technique, efficacy, precision, or care is taken from them.

There is still this aspect of the delicate touch. I still think you need to be skilled, and you will still have the opportunity to kick ass with that thing, you know, be the best and stuff like that. Like with that guy, man was he fast, and they really appreciated him and stuff.

(Liva, production technologist, robot developer, WIPER)

Closely tied to pride, professional achievement can provide a person with a new identity. People tend to attach an identity to their jobs. An identity built on achievement may also include some sort of pride, status, or value that comes from earning a particular position or salary. Achievement can also be a way of distinguishing oneself from one's peers.

Now I am in charge. Before, I worked much harder than now. Now my work here is very thin. Work is very good because I just received my diploma. My diploma, I got it last year from the greenhouse. I just got this diploma as agriculturist to lead the whole greenhouse. But what I take care of, everything I am in charge of: to water the bush, to hold, to control all the labor. I do it all and that's it.

(Omar, farm worker, affected stakeholder, SANDY)

If a person's particular skills are changed, their work made less complex, or even replaced by a basic unemployment income, the measures by which their identity is forged may be altered and thus the person may experience a loss of identity or reduced professional pride.

> *It helps lifting, it helps handling these heavy lifts, and it helps mounting. Is there something it can't do or shouldn't do? I mean, what is left for the man today, the construction worker? What should he do now? He's just supposed to operate it, right? So, it has pretty much taken over everything he used to do. I don't think his job has become more or less boring or exciting or interesting, I think it's equally interesting. It still requires a human being to get those panes into those frames, because sometimes they're a bit crooked and sometimes they're a bit, I don't know, popping them into the frame takes a delicate touch, and I think that's exciting whether it's with your hands or with a robot and I don't think that's going to change. So, I don't think he's going to get a crappy job all of a sudden. I think it's just as much fun, if the robot worked. It's not going to be boring or anything. But it's not like at a factory or something.*
>
> (Liva, production technologist, robot developer, WIPER)

The consequences of widespread use of technologies might include a collective loss of skill (navigation by charts) or even a change in our physiology (weaker hands) or social relations (colleagues).

One of the most basic changes automation introduces is the reduction of complexity in the performance of manual labor. However, from the perspective of workers in REELER (e.g. WIPER, SANDY, SPECTRUS) it may be both faster and 'better' work when done manually. It becomes difficult for the worker to envision the robot as an assistive device when the robot interferes with the quality and efficacy of their work.

> *Samuel: "Nobody wants to use the damn thing. It's too slow. That is because, you see, today there are two workmen and they do it in these, between four to five minutes, so we want to be faster than the workmen."*
>
> *Interviewer: "Ah, okay. Because, then, if not, they can't be bothered, then they will just do it manually?"*
>
> *Samuel: "That is exactly it, then they will think, 'Then we might as well do it manually, because that's faster.' Had it been sold in that state, those construction workers would have just left it in the corner and used their hands instead because it simply took too long."*
>
> (Samuel, product innovation manager, robot developer, SPECTRUS)

One reason that performance is so important is that it relates to professional pride, but also to one's income and job security.

Further, there are significant effects of partial automation that may be perceived as negative for human workers and which could lead to resistance. It could be that non-robotic solutions, like better working conditions, might provide relief without resistance.

> *Emanuel: "I remember the industrial revolution and there was a lot of resistance to the machines but it's impossible to stop that. What's important and I think it's the experience we should remember, is that we should create the social opinion and the political myriad to avoid the negative consequence of that change."*
>
> *Interviewer: "What would be negative consequences?"*
>
> *Emanuel: "The negative if we translate this metaphor from the beginning of the industrial revolution workers should work harder, should organise in labor associations, etcetera, to limit the number of hours, to create the social conditions of the welfare state."*
>
> (Emanuel, exhibition coordinator, affected stakeholder, BUDDY)

10.6 Consequences of perceptions

When we move close to our affected stakeholders' everyday lives and their experiences and conceptions of work, we also get a better understanding why humans sometimes surprise the robot makers by resisting or even sabotaging the robots that robot makers envisioned as welcomed relief. Humans often have concerns from anticipated effects of automation (real fears) and from actual experiences with automation (realized fears).

> *It [fear] can occur, perhaps with well-educated patients who work in the field of technology, which is why they know that technologies may have limitations. If we take the patients who may have a bit less technological knowledge instead, then they are a bit more prone to be positive about technology.*
>
> (Marco, technician, robot developer, REGAIN)

If fear or experience of loss of collegiality, identity, or pride are left unaddressed, the fears or concerns may lead to non-use, misuse, or sabotage. The root of this tension can be attributed to a clash of values, where the workers' values – i.e., what makes work meaningful – are threatened by automation decisions, reflecting the robot developers' and robot buyers' values.

In REELER's ethnographic research, resistance to robots was most prevalent in cases where workplace robots are operated by a worker (i.e., physiotherapists in hospitals and care centers, and construction workers at constructions sites), as opposed to other cases where robots are intended for individual use (companion robots, or autonomous cars) and/or are more autonomous and thus not necessarily used in direct collaboration with a worker (autonomous cars, agricultural robots, e.g.). Thus, we define **technology resistance** as the passive or active opposition to a technology, in response to real, lived experiences, where there exists an informed and intentional rejection of the technology. This is in contrast to **technology apprehension** which is based on a lack of experience (as elaborated in *7.0 Learning in Practice*). Both resistance and apprehension can be mitigated to some extent by training and involvement in the development and implementation processes. However, technology resistance may be more worrying for robot makers, because it involves a direct rejection of their technology in response to realized fears.

Technology resistance: *Opposition to an implemented technology, whether by passive non-use, active misuse, or deliberate sabotage.*

At one point, I heard some negative remarks, sort of 'now there won't be as many of us', and 'why this and why that', right? And we had told them not to run with the machine, but he couldn't help himself. He used it, and the way I saw it, it was like a toy. And if it can't be a toy, then you will see opposition. Then I don't think it's possible. The biggest showstopper is probably if the craftsman refuses to use it. We experience that even today. Because of the environmental regulations that are in place, many sites have machines present, but they aren't being used. They are solely used when [a workers' safety organization] shows up.

(Valdemar, engineer and CEO, robot developer, WIPER)

Non-use, misuse, and sabotage

There is a history of resistance to automation that extends at least as far back as the first industrial revolution with the Luddite resistance. Contrary to the popular usage of the term, **Luddism** was not stemming from technological naïveté. The Luddites were experts in their work and knew that the mechanization of their labor entailed a loss of control over the meaningful nature and products of their labor. Informed technology resistance to these changes may include non-use, misuse, or even destructive forms of sabotage of the robotic technologies.

Luddism: *(historical) A movement by English textile workers to oppose the introduction of machines that would diminish their craft and undermine labor practices; (popular) a derogatory term for technological apprehension; (modern, Neo-Luddism) an anti-technology lifestyle/movement.*

- **Sabotage:**

Mathias: "Some get very offended and they try to sabotage the robot itself. The robots are not bulletproof in any way. You cannot have a robot that could cope with any [every] type of situation. And also, the sensors have flaws. So, once you know the robots just a little bit, you can easily sabotage them."

Interviewer: "Have they done that? The users?"

Mathias: "Yeah, definitely. Or, even worse than disabling them, they drive into them with their transportation vehicles that they have in the buildings."

Interviewer: "Why would they do that?"

Mathias: "Frustrations of some kind. That's what we guess, because we don't understand why somebody would drive into a robot and destroy the front of it."

(Mathias, system integrator, robot maker, SPECTRUS)

Maybe if all these workers see that the robots are getting inside this workplace, they will get crazy (Laughs).

They will get crazy. I mean, maybe they will go and break it [the robot]. Or steal it also. I mean, if you are stealing their food what do you think that they are going to do? You have to eat every day. And if you don't find a job. I mean, this is really hard.

(Aramis, agricultural engineer at a seed company, affected stakeholder, SANDY)

Such resistance often occurs as a defense of workers' values (collegiality, pride, identity, achievement, etc.) against the degradation of their skills by technologies, as well as loos of income, as was the case with the Luddites.

- **Non-use:**

> *The crux of the issue is that it needs to improve the present situation [working conditions]. And if it doesn't do that, both conditions and also efficiency, then the workers immediately put their foot down. If the machine messes with their earnings, then it will be unused. Or if it is perceived as a hassle to use. Hassle can mean a lot of things.*
>
> (Valdemar, engineer and CEO, robot developer, WIPER)

The consequences of resistance can be a breakdown of the work process, with financial costs and safety risks

- **Misuse:**

> *A simple example is the emergency stops: once you push the physical button, the robot cannot release it itself, it needs to be released by a human. And by that, there could be hours of a robot just standing still in some random [hospital] hallway where you have users who don't understand why it's standing there.*
>
> (Mathias, system integrator, robot maker, SPECTRUS)

If such resistance is a defense of the meaningful work life, how do we address these issues? Who should be responsible for the loss of one's colleague? For decreased social interaction at work? For the sabotage of a robot? As robotization becomes more widespread and with recent workers' rights revivals, acts of resistance may become more organized – like the dockworkers recently decrying the automation of the Port of Los Angeles (Smith 2019). These are societal questions that demand a societal response, involving more than robot developers and users, but also robot buyers and policymakers.

10.6.1 Universal basic income

Already tested in California and in Finland, the idea of universal basic income has emerged in part as a response to fears and predictions of mass unemployment due to automation (*see also Chapter 9, section 9.2.4.*). This organized political response would seem a practical solution, but REELER participants who were presented with the idea of universal basic income were sceptical. Many of our participants were concerned with replacement and feared the permanent loss of income, but were nevertheless opposed to universal basic income as an alternative to work.

People do not want to give up their meaningful work for universal basic income.

STORY FROM THE FIELD:

Rejecting universal basic income

"If the company buys a robot to assist my work, and if they see that they spend less money with the working robot, they will put me on the street and put the robot to do the ironing. I will be without a job, that's what I think. That's why I say that I do not want it to do the ironing, I want it to fold the towels. I like ironing. I need to work."

Paloma was afraid to be displaced by a robot, despite her level of skill, commitment, and experience. She was particularly concerned that she was too old to be reskilled. REELER has found that a lot of automation affects particularly vulnerable people, who may be in their area of work because their options are limited (by their level of education, their literacy or language limitations, their life circumstances, or by their immigration status) .

Interviewer: "If you had an unemployment salary, would you work in another area or try to finish your studies?"

Paloma: "Girl, to study at this age, for the love of God!"

Interviewer: "You think you can't study now because you're too old?"

Paloma: "Ah yes! I will turn 50 soon, if I go back to school, they will ask why I am there with so many years behind me."

Interviewer: "Then, what would you do? If it wasn't anything here in the hotel, as we already know that you like to."

Paloma: "What I like is to iron. I used to work inside people's home to iron clothes for them."

Interviewer: "Why do you like it so much?"

Paloma: "I just like it; I don't know why. I really like to iron."

Interviewer: "So, you wouldn't give up even if you had to go for something else to do, you would simply always look for something similar to this area?"

Paloma: "Yes, and I wouldn't like myself at home not doing anything, because I really need to work."

Interviewer: "But you would receive money from the government."

Paloma: "Even so, I like to stay at home when I have days off. In my free time I like it. However, from Monday to Friday I like to leave my house to work. But even if I did receive the unemployment salary, I would go to people's houses. I mean I also have to find people too."

Paloma appreciates the routine that her Monday-through-Friday job provides her, and she relishes her leisure time. Despite her work being especially taxing, she would prefer to keep working as an ironer, even if she was no longer dependent upon ironing for income.

(Based on an interview with Paloma, cleaning staff, affected stakeholder, SPECTRUS)

Most of REELER's participants (robot developers included) feel the same way as Paloma; they would want to continue with their occupation even if they were offered a guaranteed basic income. Workers find meaning in work that extends beyond the remuneration of their labor. They say things like: *"A person can buy a machine but not a person; Despite all the work we do here, it is not the money that keeps us here"*. And *"Of course we get money to be here, but I don't think it's the money that keeps us here; I don't like staying at home"*. And *"I like working; You would get tired of sitting there"*. Or *"I would like to work with elderly and kids. This would be something I would like to do, to help, because there are so many people who need help"* and *"If I one day came back home, I wouldn't know what to do with myself, but I like to work with children. I would like a job in a kindergarten, something like that. Or take care of the elderly, I also like the elderly!"*

(Voices from various affected stakeholders, SPECTRUS)

These statements and the above analysis show that work is much more than labor (Voice 2015) and income; it may also provide a person with skills, a source of pride, some sort of identity, and collegiality. If these aspects of meaningful work are threatened by an automation decision, workers seem ready to resist the implementation.

Besides an income, the affected stakeholders interviewed in REELER are seeking a meaningful work life; a job that provides them with a sense of accomplishment, a social life and respect. Thus, universal basic income is an incomplete answer to technological displacement, solving only the question of Arendt's labor as means of survival, but not providing a viable substitute for meaningful work (*see also section 9.4.2 in Economics of Robotization*).

10.7 Concluding remarks on Meaningful Work

Though the REELER study is not a comprehensive quantitative study, it does point to a number of 'black swans' (*see Annex 1 Methods and Methodology*),[2] i.e., some questions that have not been thoroughly answered in the previous debate on robots and work. This chapter has explored how the meaningfulness of work can be at odds with robots and automation processes. The purpose of this chapter is to direct attention to these problems and to suggest a distributed-responsibility approach to finding solutions (*see 4.0 Ethics Beyond Safety*).

We basically find two understandings: work as labor and work as meaningful. We have discussed how these perceptions affect automation decisions, uptake, resistance, and proposed political solutions like universal basic income. Technological determinism shapes views on automation and the worker for both the workers, owners of enterprises and robot makers. Such viewpoints are wrapped up in the replacement and relief discourse which is cultivated in the inner circle of robotics where robot makers are (as seen in our Human Proximity Model) often so engaged in technology-driven solutions that they fail to see the kind of relief affected stakeholders and end-users might actually seek. Though robot makers may regard work such as cleaning and ironing tedious or hard labor, this work may be meaningfully connected to a worker's skills, identity, and collegiality. The consequences of an inevitable full-automation approach may be a lost chance for shaping ethical automation that upholds these values, and may risk stakeholders being put off – or even resisting – robotics.

Replacement is the single most prevalent issue related to work and automation, and it reveals underlying ways of thinking about human workers (as commodities) and a rhetoric of relief as a justification for replacement. It also shows that somethings about the human may be irreplaceable. When developers frame the human worker as a component alongside the robot in the workflow, they make it easier to consider them interchangeable with machines. If developers see humans as more than a production means, but as rich and complex persons, it may lead to better considerations for where robots and humans are needed respectively, and where robots are inappropriate or harmful.

Robot makers (developers and those they collaborate with to achieve automation) have an opportunity and a responsibility to shape future work towards continued meaningfulness through their automation decisions, by protecting the values workers hold in relation to work.

If robots are to be a part of our future work lives, it is essential that we ground the development and implementation of these machines in a firm understanding of the work and the workers where these robots will be situated (*see 7.0 Learning in Practice*). A closer proximity between robot makers and affected stakeholders could provide such understandings, as REELER has endeavored to do with its ethnographic research.

2 see responsiblerobotics.eu/annex-1

Chapter 11

Gender Matters

”

I think there's a difference between those who produce the robots and those who actually utilise them. I don't think there's any gender imbalance really with how they're used.

(Conor, recruitment agency general manager, affected stakeholder, WAREHOUSE)

◀ Normative gendered perceptions can become embedded in design.

11. Gender Matters

Disrupting an inequitably gendered society

You will find here

- Discussion of the question of gender and gender biases in robotics and the industry
- Empirical examples of the typical gender-related challenges that come with the design and use of robots

You will acquire

- Awareness about feminist perspectives on robots and robotics
- Awareness of the role and relevance of female perspectives and female experiences in robotics
- Gain sensitivity towards gender biases in robotics

Among different ethical concerns robot developers face in their work, one challenge is particularly pressing: Gender equality. When selecting cases for the purposes of the REELER research, gender was not a factor, though we were careful to include also female robot developers if we found them in our case studies. However, as it turns out, several important patterns emerged across all cases in relation to the role and overall presence of women in the design and use of robots. When we first noticed this pattern, we had made 163 interviews (some of which were 'extra material – and the number since grew to 177, see Methods and Methodology, Annex 1 responsiblerobotics.eu/annex-1). Of these 163 interviews we noted that 118 were with men, and 59 of these were male technical people, mostly engineers and 10 of these headed robot developing companies as CEOs. We only have one female CEO in our data material – and to our surprise only eight of the 14 female robot developers we had interviewed were actually engineers. The rest were working for robot developing companies in many different functions such as HR, marketing directors and policy makers. We had two cases (in construction and inspection) without any female robot developers at all. In other words, even if we were aware of the need to hear the voices of female robot developers (especially engineers) there were hard to find. If we did not explicitly seek to represent more females in our project, we would have ended up with even more male engineers.

Among the affected stakeholders, the gender representation differs in relation to types of robots. In the case of cleaning robots, almost all developers were male, whereas almost all affected stakeholders were female. In relation to other robot types the representation of gender was more balanced however with more females in areas tied to health than for instance inspection. We have therefore devoted a whole chapter to this issue to raise awareness that gender is an issue in making responsible and ethical robots – even though we have touched upon this issue in the chapter on Inclusive Design (*see 5.0 Inclusive Design*). Gender inequality in design is not just a matter for the engineers to solve – it includes society as a whole.

Why is an absence of female engineers and robot designers an ethical problem? The question of gender in robotics continues to be bound to the distinction and relationship between men and women and the related absence of female perspectives in robot design. The latter emerges as an ethical problem both in terms of underrepresentation of women in the robotics sector as well as overlooking women as end-users /affected stakeholders with their own needs and viewpoints. Thus, it is not gender per se that raises concerns but the bias that may come with an unacknowledged discrimination between perspectives that include different working and life conditions for men and women. Though REELER has not been able to research if the lack of female voices among robot makers actually affects the types of robots that get funding and are realized, we can raise the awareness that this may be the case. Thus, it may very well be that more female engineers – *and* more voices of female affected stakeholders – may lead to new types of robot engagements. Thus, the gender perspective holds the potential of disrupting the field of robotics.

These cleaning ladies from Portugal for instance have many good ideas for robots, which may have been realized if the situation of cleaning staffs (mostly women) were taking more into account. Here they are talking about the robots they would need to clean houses at a resort with many stairs and high ceilings.

> *Carmen: "Aesthetically, it had to be a robot that managed to get up very high because we don't manage to take away the spider webs. Or some arms that are removeable, that raise the hands."*
>
> *Malena: "And the houses are also big."*
>
> *Carmen: "It has to be malleable in the knees to climb stairs because here all entries and exits have stairs, and there are also stairs in the storage rooms. For a robot to bend the knees they have to be malleable. I'm talking of knees, but also of its feet."*
>
> *Interviewer: "And the arms also need to have the full range of movement."*
>
> *Carmen: "Exactly. A robot can't occupy a lot of space here. And it must turn around, and I don't mean 180 degrees, but a robot needs to be able to turn 360 degrees because we move a lot."*
>
> (Carmen and Malena, cleaning staff, affected stakeholders, SPECTRUS)

This type of cleaning robot that can help, and not replace, the cleaning staff has yet to be developed. Looking at different working conditions from the perspective of *male vs female* makes it possible to become aware of how the present-day situation may be ripe with unacknowledged unethical gender inequality. This is because bias involves thinking or treating other individuals differently based on perceived characteristics of such individuals, which often leads to unjust discrimination (Howard 2018) and ignores the actual people and their practices (Report 2013). A different way to discuss biases is by focusing on stereotypes. In general, stereotype is a widely held and simplified belief about a specific group of people and it is embedded within wider cultural and social institutions. Gender stereotypes reflect normative notions of women and men, typically portrayed as binary opposites (Report 2013). While 'sex' concerns biological qualities that determine whether an individual is a female or male, gender refers to a socio-cultural process and social meanings attributed to men and women (Report 2013)(Criado-Perez 2019). From this perspective, the topic of gender is closely related to that of culture and the need for an inclusive design (*see 5.0 Inclusive Design*).

Sex: *biological characteristics that classify an individual as female or male*

Gender: *socio-cultural process and social meanings ascribed to men and women (Report 2013; Rüst 2014)*

Over the centuries, the overall exclusion of women from different institutions and socio-cultural spaces or the gendered division of work was justified by 'natural laws' or 'tradition'. However, nowadays, there has been a growing recognition of the arbitrary and cultural character of gender stereotypes and roles (Rüst 2014) also in relation to design (Schiebinger 1989). In science and engineering, the nature of discrimination against women has gradually changed from overt discrimination to more subtle unconscious and often unintentional biases (Schiebinger 2008). This chapter aims to help identify and understand the existing gender stereotypes in robotics as well as propose alternative ways to bring more gender balance to both the design and use of robots based on REELER research.

11.1 How gender comes to matter

Over the centuries, different answers were given to why we see so few women in science (or the women scientists we know about) (see for instance Schiebinger 1989, Hasse and Trentemøller 2008). Nowadays, while we have a better understanding of how women were excluded from scientific institutions, the problem of underrepresentation of women in science and engineering persists. Efforts to monitor women's participation in science started in the 1980s with the involvement of national governments and international agencies. Such efforts were subsequently followed by different initiatives and policies aimed at supporting women's participation in science and engineering in terms of education and career (Schiebinger 2011). One way to better understand different levels that require efforts to remove gender bias from science and engineering is to "fix the number of women" to increase their participation and competitiveness in science and engineering. This imply "fixing the institutions" and male-dominated cultures that come with them as well as "fixing the knowledge" with the goal to enhance human knowledge (Schiebinger 2008, 5). In other words, by 'fixing' science cultures so more women can be included, the knowledge, interests and engagements changes as well (Hasse and Trentemøller 2008). This implies that more women in engineering are not just a question of balancing the *number* of males and females, but also an effort to ensure that other priorities and interests are represented. Efforts to increase and acknowledge women's contribution to the robotics field include such initiatives as establishing an international professional organisation dedicate to women in science and engineering, IEEE Women in Robotics (WIE), and regularly listing the top '25 women in robotics you need to know about' by the Robohub online platform[1]. And yet, as is clearly seen in the REELER research, still much needs to be done to achieve the actual gender balance in robotics.

The underrepresentation of women is of course a much wider issue than robotics. In the technical areas of the engineering sciences, it can be detected already with the beginning of computer science and related fields that have been developed before or in parallel to robotics. For example, Marvin Minsky, one of the founding 'fathers' of AI, said: *"AI is the science of making machines do things that would require the intelligence if done by men"* (Minsky 1968, 23). This quote is typical in so far, no explicit attempt is done to exclude women – it is 'only' an expression of normative thinking (*see 5.0 Inclusive Design*).

As both fathers and creators, men can be said to be the sex that has carefully and culturally forged AI and robotics in their own image (Richardson, 2019). The result of this deeply male-dominated culture is that the male experience, the male perspective, has come to be universal, while the female experience has been overlooked. It is the product of a systematic way of thinking, because across different domains, when we refer to the human, on the whole, we often mean 'man'. Feminist and social theorist, Simone de Beauvoir made the point most famously when in 1949 she wrote: *"Humanity is male, and man defines woman, not in herself, but in relation to himself; she is not considered an autonomous being" (de Beauvoir 1949, 27) and "He is the subject; he is the Absolute. She is the Other"* (de Beauvoir 1949, 27).

A new technological context makes the need to address gender equality even more urgent when it is primarily males who are designing a world that profoundly impacts the world for everyone. As not much is written about women in robotics, we turn to the general development of the computing sciences to get a wider picture of gender in the applied sciences.

Robotics has the potential to challenge the existing gender stereotypes in many ways. For example, some robot developers pointed to the possibility to reduce or eliminate the gap between men and women in the sectors where human physical features and capabilities will stop playing any role. This included developing a robot that in order to be functional needs to be assembled by two persons and applying the same lifting standards (similar weight limits) for both female and male operators.

1 https://robohub.org/25-women-in-robotics-you-need-to-know-about-2018/

> *Today, many jobs require big, strong men or little, petite girls. That will be evened out dramatically within the next generation or two, because physical exertion will be much less needed within industrial work. I think it will disappear, or at least diminish. I also think the requirements to operate the machines will be different.*
>
> (Valdemar, engineer and CEO at WIPER, robot developer, WIPER)

Given men's overall interest in engineering and robots, the introduction of robotics technologies to women-dominated sectors, such as for example healthcare or primary education, can potentially attract more male employees and contribute to the social change that comes with redefining the existing gender-related roles and identities.

11.2 The general lack of women in technology

The narrative of technology exposes, seen through the lens of gendered structures, a gender data gap, i.e. "*a gap in our knowledge that is at the root of perceptual systematic discrimination against women, and that has created a pervasive but invisible bias with profound effects on women's lives"* (Criado-Perez, 2019 editor's note). It is male data that informs the majority of what we know. In particular, early computing literally defined the process of computerization to this day at the expense of women contribution. For example, as discussed elsewhere (Hicks 2017), in the 1940's in the UK, computer operation and programming was viewed as women's work. Soon, women became synonymous with office machine operations and their work became tied to typewriters, desktop accounting machines, and room-sized punch card equipment. It did not take long for offices to accept the idea that competence in working with machines was a feminine attribute as opposed to the more intellectual work done my male counterparts. Women's alignment with machine work in offices persisted through waves of equipment upgrades and eventually through the changeover from electromechanical to electronic systems. Yet, the physical segregation of gender in the workplace and the fact the women's labor in the workforce was considered unskilled, presented female workers with fewer opportunities for promotion or a career. In other words, slowly, but surely women were pushed out of the industry, and computing experienced a gender flip in a field that was assumed to be rote, deskilled, and best suited for women - a sign of specific gendered labor hierarchies - until the rise of technocratic ideals in the 1960's, that reshaped the status of machine workers. Gender-segregated categories of work persisted in defining women's economic position as lower than men's, and in making women's economic lives secondary

The only woman found in an active robotics lab. Photo by Kate Davis.

for most of the 20th century (Hicks 2017) and continues until today.

Sexuality plays a silent, but critical role in the history of computing. Coding was originally seen as a women's game, before the machine that took their name replaced them and took even more years before they were replaced by men. Women's labour had become so closely allied with computers that some machines actually took on their identities, for example BETSIE (a betting and bookmaking computer) and SADIE (which stood for Sterling and Decimal Invoicing Electronically) (Hicks 2017, 125). As the 1960's progressed, advertisements showed woman's computer work as simplistic, and 'dumbed-down' the job, in order to better sell machines. So much so, that in many later images, women were used to showcase machines and advertising went from focusing on machines and workers, to focusing on primarily (female) workers. The machines (they built) would disappear and the female workers became objects of desire themselves - men's ideals about women's sexuality used to structure jobs in computing. This layer of sexual subtext on the representation of women in the field of computing blended with the shift already underway and the expectations about women's lives based on a form of mid-century heteronormativity, that left most women with limited career prospects (Hicks 2017, 5). To this day, despite decades of equal pay legislation and significant investments in educational strategies across different countries, patterns of underachievement and perceptions of women as less technically competent persists, including within Anglo-American culture, business, and high-education (Hicks, 2017 231). Yet, this image is a recent historical construction and a distinctly masculine perception that computing has acquired, and is not a fair reflection of women's skills, ability, and interest.

Turning to the uptake of undergraduate and, graduate, faculty posts and business relating to AI and robotics, for instance, we still see a significant gender difference/imbalance. The upper ranks of academia – particularly those in STEM fields - are dominated by a majority of white, middle-and-upper class men. When compared to other industries (including non-STEM), the information technology industry had the lowest representation of women – 28.4% of companies surveyed still had zero women on their boards in 2017 and only 18% had three or more women (Catalyst 2019). However, women in Europe are gradually closing the gender gap in science and engineering, with an increase of women who made up more than a third (40.5%) of scientists and engineers in the EU-28 in 2017, yet negative work experiences impact women's decisions to leave – isolation, male-dominated work environments, bias and lack of effective women role models are all factors pushing women to leave STEM jobs – they are 45% more likely to leave than men (Catalyst 2019).

REELER has not explicitly looked into the lack of women in technology-focus careers, but the significant lack of women as engineers and CEOs of engineering companies in our case studies indicate this as a major ethical problem in engineering. Awareness about gender issues would, if embedded in robotics, create new knowledge about how government practices and new technologies can challenge, perpetuate or undermine social and economic equality.

Following feminist studies there is a need to counter the assumption that gender equals biological sex, and that women by nature differ from men in their ability to create (due to biological sex). By countering this claim, we make sure that the differences in representation of males and females in the REELER data, it cannot simply be explained as because women do not want to work as CEO's or engineers. Creating a distinction between sex and gender is critical to ensure that we are not mistaken in the idea that biology is destiny. For a long time, feminists have challenged the synonymity of sex and gender and believe both have two, very different meanings – and inequality is culturally shaped, not biological. Although, it is important to acknowledge that there are biological differences that are unique to male and females, many of these differences are relatively minor compared to the vast, socially constructed gender differences we see in some Western and some Asian cultures; such as the classical social roles ascribed to men and women; men need to be the assertive leaders, workers and breadwinners, and women must to be passive, domesticated mothers and wives. It is crucial to ensure that robot makers as well as engineering and indeed society in general move away from such socially constructed gendered norms and do not allow these existing ideals to manifest into the development of robots and AI.

Feminism: *The advocacy of women's rights on the ground of social, political and economic equality of the sexes.*

In response to this, it is important to set out theoretical feminist positions to inform studies on gender and ethics. A new field of study has emerged, concerned to develop a feminist perspective on technology, ranging from women's limited access to scientific and technical institutions, to exploring the gendered nature of technology itself. We cannot, of course, do justice to all the contemporary feminist thought in our study, yet, hope to touch upon enough theoretical background to highlight the female politics of technology, thus key to achieving gender equality.

- *Liberal feminists* take an individualistic stance, whereby they focus on women's ability to maintain their equality through their own actions and choices. Liberal feminists seek no special privileges for women and simply demand on making the legal and political rights of women, equal to men. When it comes to information technology jobs, most engineers and others involved with information technology take a liberal feminist view and assume that the focus should be on employment, access and discrimination issues (Rosser 2005). Similarly, this is the standpoint robot developers tend to take in regard to lack of female representation in STEM fields and association of sex and gender. Liberal feminism does not address the potential of gender to affect 'fundamentals' and reaffirms, rather than challenges positivism and individualism, suggesting that 'fundamentals' would always remain the same - gender and sex (Rosser 2005, 2).

- In contrast, *socialist feminism* rejects individualism and positivism. The basis is formed under the Marxist-social theory and work of numerous scholars of technology have produced large amounts of research, commonly known as 'the social shaping of technology' (Rosser 2005, 3). This term brands information technologies as a social product and suggest that information technologies comprise human activities (Rosser 2005). Socialist feminist critique includes women and place gender on equal footing with class in shaping technology; capitalism and patriarchy function as mutually reinforcing parts of a system, where the sexual division of labour stands with wage labour. This is a central feature of capitalism and drives patriarchal and power relations in society, that has limited the work done by women. As a result, middle-and-upper class men tend to create and design most new information technology and serve as the sources of money for design, and creation. Socialist feminist reform suggests that the allocation of resources for technology development should be determined by greatest benefit for the common good (Rosser, 2005), and this approach would lead to better inclusion and ethical decision making within the development of robotics and AI.

- An alternative approach began developing in the early 1980's, what is often called *'difference feminism'*, and holds the idea that there are differences between men and women, but not as argued in liberalism and biological determinism. Difference feminism did not argue that there was an inherent link between women and traditional feminine values, but instead sought to recognise that women and men are significantly different, and to revalue qualities that our society had devalued as 'feminine', such as empathy, tolerance and cooperation (Schiebinger 1999). The 'superior nature of women' could reform science, by directing knowledge away from the pursuit of power and instead, toward greater equality and freedom for all humankind (Schiebinger 1999). It has been said that women have distinct ways of knowing, that has been excluded from the practices of science, largely due to the domination of men in these fields, and when making moral judgments, that they value context and community over abstract principles (Schiebinger 1999). Difference feminism believes that attributes generally tied to women have been excluded from science and gender equalities have been built into the production and structure of knowledge. However, post-modern feminists have pointed out that this framework to easily posits a 'universal woman', and excludes the notion that women have diverse histories, needs and aspirations (Schiebinger 1999).

- *Radical feminism* aims to dismantle the patriarchy and views patriarchy as dividing societal rights, privileges, and power primarily along the line of sex, and as a result, oppressing women and privileging men. Radical feminism rejects most scientific theories, data, and experiments not only because they exclude women, but also because they are not women-centred (male perspective). Because patriarchy pervades and dominated all institutions, ideologies and technologies, women have difficulty placing their experiences, lives, and needs in central focus in their everyday lives and environments - gender bias (Rosser 2005). We have learnt that the domination of men and the absence of women from the design process in fields of STEM, is a factor to why we experience technologies which are closely aligned to the needs of men and therefore do not consider the requirements of women. Radical feminism suggests that because men, masculinity, and patriarchy have become completely intertwined with technology and computer systems in our society, no truly feminist alternative to technology exists (Rosser 2005).

Also, it is important to observe that the dominant cultural ideal of masculinity has an intimate bond with technology. Through the lens of computerisation in society and the gendered division of labour, men have been known to affirm their masculinity through perceived technical competence and assert women as technologically ignorant and incompetent – attitudes that still reflect in our present technical culture (Wajcman 2010). As a result of these social practices, women may attach very different meanings and values to technology (Schiebinger 2008). To emphasise the ways in which the symbolic representation of technology is sharply gendered, is not to deny that real differences do exist between women and men in relation to technology, nor is it to imply that all men are technologically skilled or knowledgeable. Rather, it is how the male perspective has, in turn, become universal and one with machine (Wajcman 2010).

Engineering culture has been said to adopt a quintessential masculine image. So much so, that of all the major professions, engineering contains only a small proportion of females. For example, as far as the UK is concerned (the country that after all is a pioneer of the Industrial Revolution), it has the lowest number of women in engineering occupations in Europe, namely 12% (Neave 2018). In modern societies, the education system, along with other social institutions, plays a key role in the formation of gender identity. They add values and meanings that can identify with rigid ideals of masculinity and femininity; not allowing young people to escape that pigeon-hole. There is now a lot of coverage on sex stereotyping in general schools and addressing the processes in which girls and boys are channelled into different subjects and interests. There are links between education and the extreme gender segregation in the labour market, particularly in STEM fields, and this must be set about, providing schemes to open up opportunities for women to enter into technical trades.

Lastly, concentrating on gender in this chapter, allows us to look at how the design and use of technology are shaped by male power and interests, which not only exclude women but also men who do not fit the male designers norms (Schiebinger 2008) and insists that technology is always the product of social relations (Wajcman 2010). A very extreme and recent case of this within the robotics and AI industry, and a reflection of gendered (patriarchal) design, is the development of sex robots. These machines are a new addition to the sex trade that commodifies the female body. Sex robots are a reminder of the patriarchal system that constructs our society and reinforces relations of power that do not recognise women as fully human. A company behind the build of these robotic ‘lovers’ is RealDoll by Abyss Creations, who label these devices as ‘companions’ for people who struggle to form and sustain lasting relationships with fellow humans, due to social, psychological and/or physical reasons. No matter what creators and consumers claim about the harmlessness or social good of sex robots, they project clear messages about male entitlement and what women are good for - male gratification. Technology is never innocent. Though REELER did not study sex-robots as a case, we still emphasise that ethically we must resist any forms of robotics and AI which perpetuate damaging norms, including sexual norms and inequalities in society, whether it be through the design of robots or the application of them.

11.3 Key issues for gender awareness

In general, the subject of gender in robotics concerns as much the wider field of robot makers, including robot developers, as their creations. While some of the findings came as no surprise, like the underrepresentation of women in the robotics field and STEM industries, what does raise concern is the way a predominantly male perspective may affect the outcome of robot developers’ work. This is particularly true for the cases where predominantly male roboticists develop robots for sectors that are dominated by women, e.g. education (ATOM) or the cleaning industry (SPECTRUS). In some cases, gender has been explicitly discussed in terms of ethical challenges. The following sections provide examples of how the question of gender emerges in practice in robotics and in relation to broader socio-cultural contexts. The first concerns the underrepresentation of women in our REELER material as well as a gendered work division. The second concerns male perspectives on female realities, and the third the ‘gendered’ robots.

1) Underrepresentation of women and gendered work division

As far as robotics and robot applications are concerned, women participation is seriously limited. Comparing to men, there are much less women who are involved as robot developers, both in the academia and industry, as well as robot end-users in certain sectors. Gender is understood here not only in terms of differences between men and women but also gendering of skills, work, knowledge and social life among others (Adam 2005).

As the REELER research has shown in robotics, underrepresentation of women is something that robotic developers are usually well aware of, when asked about it. They are aware most of the colleagues and project partners robot developers deal with are men and some also wish for more women. However, the degree of underrepresentation of women in engineering varies between countries – and as we have previously seen in the natural sciences, women are more represented in e.g. physics in Italy, than in Denmark (see Hasse and Trentemøller 2008). Even if women do contribute to robot design and development, our REELER research often find them to be hired in their role of non-technical experts or assigned the tasks that require so-called 'soft skills' (social and communication competencies) that some view as 'natural' female skills (Weber 2005). It is therefore no surprise we find a relatively high participation of women in the field of social robotics and Human-Robot Interaction (HRI), whereas there are fewer at ERF (European Robotic Forum). The absence of women also is prevalent in some sectors and industries that make use of robots, for example in the agriculture or warehouse sector. This often leads to a situation where male roboticists develop robots for predominantly male end-users, and therefore, further perpetuate the existing gender gap.

REELER research well-illustrates the above-mentioned trends. In general, across all 11 cases, women constitute only 18.9% of the REELER participants among robot makers – and, as mentioned, rarely as CEOs and often in other roles than as engineers. Women constitute 38.8% among our affected stakeholders, which is also tied to the types of robots we study – e.g. robots in construction sites, where the affected stakeholders are mostly male. As shown in Fig. 11.1 and Fig. 11.2, two cases hold no interviews with women among the robot makers, namely 'OTTO' and 'WAREHOUSE', and three cases involve interviewing only male affected stakeholders, i.e. 'HERBIE', 'OTTO' and 'WAREHOUSE'.[2] One of the cases with a very low participation of female roboticists, i.e. 'SPECTRUS', included almost exclusively females among affected stakeholders (cleaning staff) and thus exemplifies the application of male perspectives to women's domains.

The underrepresentation of women among the REELER participants was due to the conditions found in the field, i.e. the access granted to the robot makers or workers who were all men. Also, even if working for or collaborating with robotics start-ups and companies, with some exceptions, women were typically in charge of non-technical tasks. For example, the development of teaching scenarios for educational robots, providing expertise on HRI and user involvement or running the company's communication and PR activities. Last but not least, there was only one female roboticist holding a position of Director of R&D.

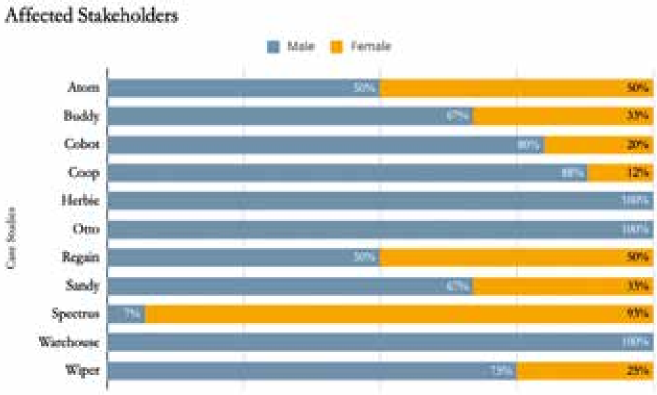


Fig. 11.1 Proportion of male and female REELER participants among affected stakeholders

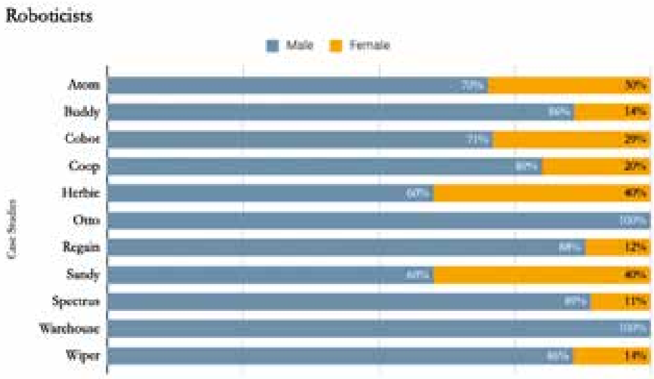


Fig. 11.2 Proportion of male and female REELER participants among robot makers

On the one hand, underrepresentation of women in robotics is due to different structural factors inherent to education and employment that foster men participating in engineering. On the other hand, the absence, or a high dropout rate, of women in engineering is also due to women's social roles that traditionally involve family assignments and the overall organisation of society that go far beyond robotics. A limited presence of women in technical fields or job sectors is also due to the roles imposed on women in the process of upbringing where girls are often explicitly discouraged from pursuing engineering careers. Both parents play a role in gender stereotyping: According to some studies, female parents are even less likely to recommend engineering to their children, in particular to the girls (Neave 2018). Also, comparing to female parents, male parents demonstrate more positive perception of educational robots in terms of their usefulness and confidence in teaching with the use of robotic aids, as well as are more willing to support children in learning from educational robots (Kwok-Kong 2012). Therefore, it can also be women's own bias that complies with the dominant male culture and make them believe that certain jobs as 'men's jobs' (note the persisting association between the notion of 'men' and 'tradition'). Such an approach fuels gender stereotypes and often turns biases into self-fulfilling prophecies (Howard 2018). In principle, some women freely choose not to engage with robotics or some types of jobs that tend to be undertaken by

2 The few participants who hold a double role of robot maker and affected stakeholder, e.g. robot end-users who actively contribute to the process of robot design and development, are included in calculating the percentage for both robot makers and affected stakeholders.

men instead. As discussed by some of the participants, some robotic companies make deliberate efforts to hire more women, however, finding female engineers and breaking a vicious circle is apparently a difficult task; there is not enough female engineers who apply for jobs in robotics (the same applies to some other male-dominated jobs). Furthermore, even the way jobs are advertised may be biased towards men and discourage women from applying (Criado-Perez 2019). The ethical implications of a gender imbalances are of course a complex issue that requires structural solutions that cannot be solved by individual engineers.

When involving affected stakeholders, whether considered end-users, or directly or distantly involved stakeholders, in the role of the study participants, they are more diversified in terms of gender. However, problems with gender imbalance still persists. It is apparent that underrepresentation of women may not strictly be the complete absence of women in a given field, but indicative of a sharp separation between the type of tasks that men and women do, the education they have and jobs they assume (the subject has also been addressed in terms of 'gender segregation' (Neave 2018) or 'gendered division of labour' (Schiebinger 2011). For example, in the manufacturing industry, males tend to be in charge of the tasks requiring physical strength while female staff are typically dedicated to small items assembly. Such a division is true for any type of jobs considered to be physically demanding. In one of the REELER cases, when training operators to use a transport inspection robot, only approx. 7% of the trainees were women, which generally reflected the employment structure of the company in question. At the same time, some sectors tend to be almost entirely dominated by women. This was the case of the cleaning sector or primary education that are addressed in the REELER research. Since most of the robot developers are men, the situation where they develop robots for female end-users without actually involving women to address their needs and preferences is highly problematic.

When addressing gender inequality across different sectors, it is important to note that closing the gap in terms of numbers (e.g. through gender quota) is only the first step needed to increase gender equality and gender balance. The change must apply to the entire male-dominated culture and the overall organisation of society, and the related male perspective treated as 'universal'. In the context of science and engineering, it may involve 'gendered innovations', such as *"transformations in the personnel, cultures and content of science and engineering brought about by efforts to remove gender bias from these fields"* (Schiebinger 2008, 4). Such a change must involve not only 'including' female perspectives (the approach that may only reinforce the view of the male perspectives as the norm one should be aspiring to) but also actively acknowledge, value and prioritise women's approaches and contribution to the design and use of robots. Moreover, it is important to note that amplifying existing gender stereotypes, robotic technologies have the potential to actually redefine our understanding and perception of gender and related roles whose consequences may go far beyond robotics.

2) Male perspectives on female realities

Male perspectives are often treated as the norm for the design and use of robots, and man is generally viewed as 'default human' (Criado-Perez 2019). Despite being half the population, women's qualities, needs and perspectives are often overlooked or analysed only as relative to male norms. Yet, male perspectives are often depicted as 'gender-neutral' and 'universal'.

The underrepresentation of women in engineering and tech industries has an explicit impact of what type of robots we develop and how we do it. This is because it is typically men's presence and perspectives that determine standards and requirements for the design and use of robots and related user experience.

Sometimes the reason for choosing male perspectives are a simply a matter of practical choices. For example, during REELER research we experienced a video demonstrating a robot in use involved a male actor instead of a female actor, because he was the only person capable to operate a machine at the time of shooting the video. More often than not, such practical reasons are inherently linked to the unconscious bias many male robot developers hold that allow them to not prioritize or even simply exclude women's perspectives. In other words, while men are taken as the norm, women are often analyzed as an afterthought and in terms of deviation from the norm (Schiebinger 2011). In this way men's perspective come to be considered 'objective' and values tied to female experiences and needs appear as 'deviant'. For example, the REELER research on construction robots show this field has been typically dominated by male workers, and a female body is sometimes viewed as 'small', and hence, 'out-of-shape'. And this is a best-case scenario because the robot designers discover 'female bodies' when they decide to include women as potential end-users of their robots. Most often these biases go unnoticed till the robots are on the market (*see 5.0 Inclusive Design*). Other studies on age and gender differences in operating a robot manipulator have shown that men are being considered to be 'better', 'faster' or 'more efficient' than women rather than simply address the differences between the individual people involved (Paperno 2019). In REELER studies we have seen that even when designers really want to include women, the main and often the only difference between genders that robot developers explicitly take into consideration is that related to body features and physical capacities. A typical example is that of categorizing a task or a job as physically demanding, and hence suitable for men, or considering different body sizes when designing robot interface. In this sense, robot developers typically approach the subject of men and women in terms of 'sex' and not 'gender' and with the male norms and values considered a main point of reference. Just as when ethics is reduced to be a matter of safety (*see 4.0 Ethics Beyond Safety*) gender is reduced to biology and not a question of different life experiences and values. This is potentially a highly traditionalist and objectifying approach where women are perceived through the lens of their bodies in the first place.

Based on the REELER findings, in most of our cases the subject of gender is nearly inexistent in our interlocutors' thinking about work and robots: When asked about the differences between men and women in terms of the use of robots or performance at work, several affected stakeholders simply stated there are none. Such thinking applies also to the perceived suitability of robots for both male and female operators. The question is, however, how often such assumptions have been empirically verified by robot developers with the actual involvement of women or by affected stakeholders who in certain sectors are predominantly men. For example, one of the robots studied in the REELER research is developed in close collaboration with the actual robot operators. In that case, however, all operators involved in the process of robot development were males. Other examples include developing solutions that would be suitable for people with small hands, including women, that, however, had the male engineer's male (and big) hands as a normative frame of reference.

STORY FROM THE FIELD:

On the 'universality' of male perspectives

In our Western culture, be it in robotics or other fields, the male perspective and the male experience are generally seen as universal (Criado-Perez 2019). Thus, even when testing solutions with the goal to make them suitable for women, in this case in terms of the size of the hands, it sometimes involved participation of men with smaller body parts rather than involvement of the actual women. In one of our best-case scenario's this process even involved a female designer. In such a case, 'our way' [i.e. male's way] to do things is supposed to count for the women or anyone else's perspective (indeed to be 'universal'):

Interviewer: "In relation to this thing about creating a model that fits every hand…You write really well about the fact that women should also be able to use it, and large hands, and small hands. How did you do that? I know I've asked about this before, but could you be more specific?"

Liva: "Well, I think [Male 1] had the largest hand, it was just, I mean, he had a pretty big hand, and for a guy, [Male 2] had a pretty small hand, and [Male 3]'s was somewhere in the middle. So, it was basically just a question of handing it to them and seeing, "How does it feel for you? What kind of issues do you have with it?"

Interviewer: "And then simply try to find a version that fits everybody."

Liva: "Yes. Simply feel our way through it."

This case was special, because they had an explicit desire to include women – which was not seen in other cases. In some cases, it is even end-users themselves who may impose gender stereotypes on the robot design. This was the case of the educational social robot. While robot developers aimed to develop a robot that does not have any specific gender assigned or can be treated as both a male-like and female-like robot, eventually they were forced to change the colour of lights in robots to address boys' preferences. Once again, it was the girls who needed to adopt to boys' (future men) preferences and accept the blue colour in robots without using the pink.

Leon: "As for the robot itself, we were trying to develop a totally unisex design here, right? So, neither for boys nor girls – universal."

Interviewer: "Because the robot has no gender assigned to itself?"

Leon: "No, the robot is a bit masculine, but for example, in the first chapter of the application scenario we have a female hero. So, we have a robot dressed up as a woman."

Interviewer: "Ah, so they get dressed."

Leon: "Yes, because we also have a lot of gadgets, applications, we can buy different items of clothing, and we have some things that are typical of women, typical for boys, but there are things that are typical of anyone (laughs). So, for both boys and girls. We noticed that for example the pink color, right? This is a generally perceived girly color and the boys don't like it. They don't like it and we often had situations where we were to split the group into two groups, one would be blue, the other one pink. Because pink looks good against the backlight. (…) And the boys are always rebelling. "No, we don't want pink, we don't want to be in this group," and then we always had to give them gold or green. And so, we decided that the primary color will be blue, because the girls accept the blue."

(Based on interviews with Leon, robotics start-up co-founder, robot developer, ATOM and Liva, production technologist, robot developer, WIPER)

Occasionally, potential gender-related challenges have been identified in relation to women's attitudes towards technology in general, and robots in particular. Gender, or rather being woman, along with old age, are sometimes seen as factors in creating resistance towards learning about and using robotic systems. Some robot makers view interest in robots as inherently 'men's thing', unless it involves women who already have technical backgrounds, i.e. are prepared to address robots. However, they did not wish to be quoted for these views. The outcome of such views is that it is female end-users, and/or other affected stakeholders, and not the male robot developers who are seen as responsible for the potential failure of the process of integration of robots into our gendered society. Only a single study participant (affected stakeholder himself) explicitly observed that the gender-related biases are not so much in the way people use robots, but instead are the ways in which robot developers adopt their own approach towards gender.

Thus, it is the implicit bias and normative thinking within the inner circle in robotics that needs to be addressed, both on the individual and collective level. In general, in order to identify and tackle bias in system design, it is important to critically engage with systematic ethical reflection (Howard 2018). This can be done only in direct collaboration with female roboticists and affected stakeholders mediated by helpers like alignment experts. Also, it would be useful to expand the focus to address not only 'gender bias', but also 'gender dimensions. The latter do not have negative connotations the way bias does (an approach similar to addressing ethics in terms of human well-being rather than only prevention of harm). Overcoming gender bias has the potential to prove beneficial for the robotics research itself: By addressing the actual women and their points of view, robot developers may develop robotics technologies that are better fitted for our society, including both women and men in all their diversity (it is often the case that changes made with women in mind also improve the situation of men that differ from the normative expectations of robot developers (Schiebinger 2008). Also, reflecting on the women's perspectives may help male robot developers to better understand and expand their own thinking as well as identify and overcome biases related to gender. Last but not least, removing gender bias from science and engineering generally helps to enhance human knowledge and technical systems (Schiebinger 2008) in novel and creative ways that otherwise could never emerge.

3) Gendered robots

Given the human tendency to anthropomorphise inanimate objects as well as human-like appearance and behaviours designed into some robots, the question of gender also literally applies to robotic systems and related human-robot interactions. This is also where potential gender bias may be more overt and explicit than in other areas of robot developers' work.

When designing robots, especially human-like social robots that resemble human appearance and behaviour to a varying degree, it is not uncommon for robot developers to assign gender to robots. This can be achieved through different means, for example the robot look, shape, voice etc. Gender is generally viewed as one of the characteristics that may help creating an anthropomorphic effect in robots and improve the social acceptance of robots. End users also tend to project gender-specific characteristics onto robots, even those far from being human-like, e.g. by giving to the robot a female or male name. One could argue that adding gender features to robots in the process of their design and development aims to facilitate interaction with robots for the benefits of end users. In practice, however, the use of gender may serve mainly to achieve particular design objectives rather than look at end-users/affected stakeholders' well-being in the first place. For example, the role of gender in robot design has sometimes been described in terms of increasing the robot's 'persuasiveness' (Siegel 2009) and its capacity to provide social clues that trigger specific responses in end-users (Tay 2014). This is how, just as in the real life, gender is subject to instrumental approaches and attempts to control the way it is perceived and experienced.

Also, as already mentioned, both robot design and human interactions with robots may be shaped by the existing gender stereotypes. A decision to apply specific gender characteristics to the design and use of robots may not only reflect but also reinforce gender stereotypes, both on the side of the robot developers and affected stakeholders. For example, one of the promotional videos identified in the REELER research shows a robot bringing a rose to a woman, apparently because it's what people like. Such an approach is of course ethically questionable (Shaw-Garlock 2016) because it shows a robot that does not exist. However, it is also cementing the gender stereotypes that are unreflectively adopted by the male engineers. A potential bias inherent to the robot design may concern not only the way the robot is designed but also how it classifies and treats affected stakeholders based on their gender. Also, the way gender stereotypes is reinforced can also be assigning specific roles to robots; for instance, robots that conform to occupational role stereotypes related to gender, namely female healthcare robots versus male security robots (Tay 2014). A different example is that of robots presented as young and attractive women performing jobs in the service industry, e.g. receptionists (Richardson 2016). This also well illustrates robot developers' tendency to focus on sex and biological features rather than gender (see above) and incorporate male views of females into the system hardware and software, often without even being aware of it. Dealing with such a bias and related practices is a much a cultural as technical challenge.

One could argue, an alternative approach is to design gender-neutral robots, both in relation to the system design as well as the conception of the affected stakeholders. However, despite claims to objectivity, science and engineering as such can never neither value- nor gender-neutral (Schiebinger 2011). We also realise it is not an easy task to create robots without gender (as it for instance has been attempted by professor Hiroshi Ishiguro in Japan with the *Telenoid*; *see photo on next page*).

The presumed genderless Telenoid robot illustrates a gender-avoidant, rather than a gender-aware, approach to design. Telenoid™ : Osaka University and ATR Hiroshi Ishiguro Laboratories. Photo by Kate Davis

Another example comes from the REELER research: As illustrated in the story above, the robot developer describes the educational social robot as *gender-neutral* or only *a bit masculine*. Yet, some of the related promotional materials that are available online refer to the robot as 'he' (in addition to calling the robot 'it'). Also, even in the situation of deliberate efforts made to avoid adding any gender-specific features to robots, it may be affected stakeholders themselves who may bring gender stereotypes to their interactions with robots that robot developers will need to face. In most cases, it is the male perspectives that will be imposed to women (see 'Story from the Field on the 'universality' of male perspectives').

All in all, from the ethical perspective, the explicit attribution of gender to robots, be it in the way we design robot hardware and software or how people interact with robots, may be highly problematic. At the same time, such a situation creates the opportunity to uncover existing gender bias and address them. It is important to note that robotics technologies and robot developers who work on them have a real potential to challenge existing gender inequality. The ultimate question and the challenge we need to collectively address is always about the kind of society we want to live in.

11.4 Concluding remarks on Gender Matters

The REELER team decided to include this chapter on gender after analysing the gender issues emerging as a pattern across the 11 cases. While the chapter on Inclusive Design directly addresses the robot developers and suggests ways to obtain a more ethical and inclusive design in general (*see 5.0 Inclusive Design*), this chapter addresses the well-known, yet still relevant, general gender imbalance found in REELER as well as in many of the studies referenced in this chapter. We do not believe this problem can be solved just by bringing more awareness about gender issues in engineering education for instance. Here we are faced with a deep and fundamental problem, that needs a societal solution. In design work it may be an impossible task to create completely gender-neutral robots. However, much more diversity and acknowledgement of other values and life experiences can surely be more prevalent in robot design – and awareness of gender issues may help acknowledging diversity.

A perspective on gender is, as also mentioned in feminist studies, namely not just about a predominantly male normativity that spills out and forms our society and its potentials. The gender perspective also points to that it is a *particular* male gaze and vision, that also excludes other male as well as female gazes and visions. The males encountered in REELER research in general shared the culture of the *inner circle* (*see Collaboration in the Inner Circle, 3.0*) as well-educated engineers or similar academic educations, predominantly white and between 30 and 50 years of age, with life experiences tied to the work with technology and collaborations with other robot makers. They do not try to exclude women or other males' perspective from their work. On the contrary, some of them express a need for a more holistic and realistic understanding of the world in which their robots are to work. However, it is hard for them to break out of normativity without help. To bridge the gap between these males and their normative culture, and the rest of the male and female needs and values found in our societies, REEER therefore suggests the need for a new type of education that ensures we have alignment experts (*see Human Proximity 12.0*). An important part of their job will be to remedy the gender imbalance.

Chapter 12

Human Proximity

"

Being an engineer, it is always difficult to see through other aspects such as ethics, societal issues, etc. – definitely when working as a designer and visionary of new types of robots. This [social drama experiment with social scientists] really helped me a lot to see some other aspects related to ethics and society that I haven't experienced before. So, designers of new androids, robots, or humanoids must take these into consideration while at the same time not withholding their imagination for revolutionizing the field of robotics.

(Yannis, at a REELER outreach event, robot developer, SPECTRUS)

◀ Physical distances between robot makers and affected stakeholders, and their different understandings, values, or motives can result in a human proximity gap in robot design.

12. Human Proximity

Bridging the gap between robot makers and affected stakeholders through ethnographic inquiry

You will find here

- The ethnographers' self-reflective process
- Overview of human proximity gaps in robotics according to REELER data
- REELER findings on how current efforts to collaborate fall short
- Definitions of collaborative learning, core- and relational- expertise, proximity gaps, common language, and cultural brokerage
- Empirical examples of proximity gaps and possible solutions involving alignment experts
- Discussion of the potential contributions alignment experts could offer
- Recommendations and tools for building relational expertise

You will acquire

- Awareness of how alignment experts can help to uncover stakeholders, 'unforeseen' problems, motives, & the situated context
- Awareness of problems to be solved with robotics vs problems to be solved by other means
- Awareness of how to develop relational expertise and agency
- Awareness of how the social sciences might contribute to design and development processes through the involvement of alignment experts
- Awareness of the need for a new type of educated alignment experts that do not exist today

In the Introduction we introduce *The Human Proximity Model* (HPM), developed by the REELER project to illustrate how changes in collaboration practices may contribute to more responsible and ethical design of robotics. A central assumption of HPM is that human proximity is a requirement for collaboration. This means that collaborative learning requires humans to be physically (or virtually) in each other's presence.

Proximity gap: *Physical and conceptual distance between persons, including differences in understandings, values, or motives (as illustrated in the Human Proximity Model).*

In this chapter, we present collaboration as it takes place in the bubble, and identify the gaps in motives and interests between robot makers and affected stakeholders. We then suggest an expansion of this model by introducing a version of collaborative learning that is attentive to affected stakeholder's motives for collaborating.

We argue that robot makers have ethical and financial incentives to further develop their collaboration skills as well as the scope of their collaborations. This will help create robots, which are useful to end users, have increased uptake, and avoid the pitfalls that result in sabotage and misuse, as identified in 10.6. We first introduce a novel way of facilitating collaborative learning through the help of alignment experts. Then we take a closer look at how robot makers collaborate with each other and end-users – and finally we discuss how our novel way of understanding collaborative learning may lead to closer proximity between robot developers and affected stakeholders. Lastly, we briefly present some of the REELER tools developed to enhance collaborative learning.

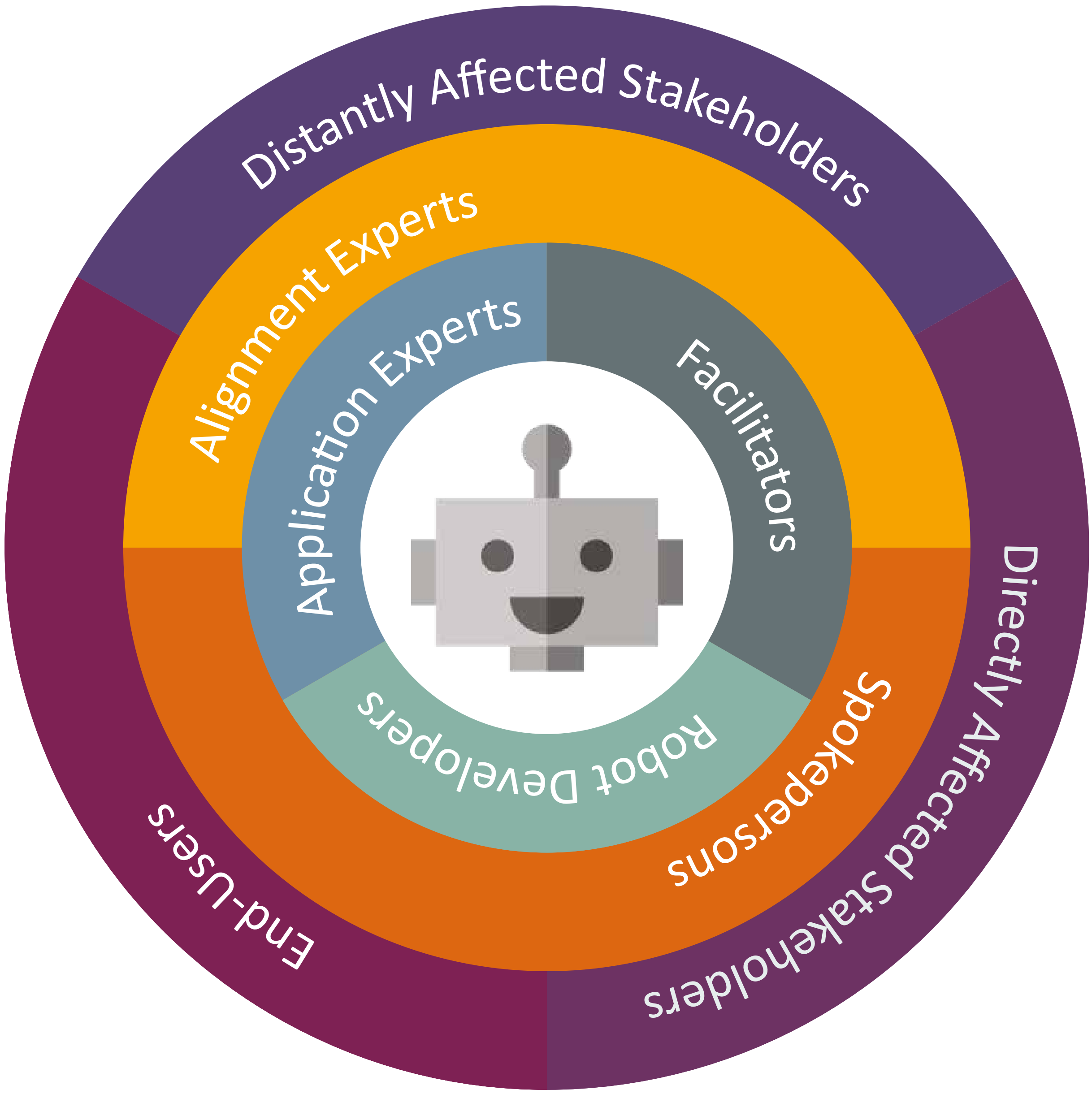


Figure 12.1. Alignment experts may bridge the proximity gaps between robot makers and affected stakeholders in robot development.

This chapter reflects on the needs discovered through ethnographic methods, and our own present-day inability to act as 'gap-fillers'. The previous chapters have presented a range of ethical issues emerging from a disconnection between robot makers responsible for the development of new robots and the affected stakeholders whose lives will be changed by these robots. This disconnection, or *proximity gap*, entails a physical distance between robot makers and affected stakeholders, but also differences in understandings, values, or motives. In the previous chapters, we presented some of the general proximity gaps disclosed by our ethnographic research. In this chapter, we discuss, from an etnographic point of view, how these gaps could be closed.

Through our research, we have acquired knowledge of robot makers' and affected stakeholders' different socio-material worlds and separate core expertise, including the understandings and values that influence their different motives in robot development (*see 2.0 Robot Beginnings*).[1] We hope that our findings can help serve as a first step towards increased proximity between robot makers and affected stakeholders, paving the way for aligning motives through **collaborative learning.**

Collaborative learning: *A process of alignment of different motives and expectations in working toward a common goal.*

1 *Robot Beginnings* (as well as *Collaboration in the Inner Circle* and *Gender Matters*) are for reasons of space not included in this printed version, but can be found in the extended online version of *Perspectives on Robots* at: www.responsiblerobotics.eu

It is essential to point out that collaborative learning occurs between people. It is thus important to identify the proximity gaps between people – i.e. robot makers and stakerholders – affected by their robots in question, and to close these context-specific gaps with increased alignment. Reflecting on the different core expertise the ethnographers, economists and robot developers brought to bear in the REELER project, we identify the need for a new type of education/profession which combines an etnographically informed understanding of affected stakeholders with knowledge of the technical and financial aspects of robot development. For this task, REELER proposes a new role in robot development – that of **alignment experts**. These experts must be educated in the social sciences (e.g., Anthropology, Sociology, or Science and Technology Studies (STS)) which emphasize methods for studying 'the other' However, while their core expertise is the understanding and translation of different motives and values between groups, alignment experts need a solid grasp of engineering and economics. This is necessary, if alignment experts are to facilitate collaborative learning btween actors with different core expertises (*see 1.0 introduction*).

Alignment experts: *Intermediaries working to align robot makers' and affected stakeholders' motives, based on empirical knowledge of both.*

This is not to say that alignment experts are the *only* solution. A lot of efforts have been made in the past and in recent years to close this gap and to ensure responsible ethical robotics by, for instance, introducing user- or human-centered design, by using application experts to understand a robot's context, by instituting codes of ethics for engineers, and by making policies and regulations.

Yet, we argue that experts in qualitative methods such as ethnography bring something new to the table, which helps robot makers lift the burden of their ethical responsibility. Instead of entering the robotic bubble as social scientists just helping robot makers in the inner circle (effectively acting as application experts), alignment experts would act as *cultural brokers* (*see section 12.3*) identifying values and motives in the spaces between robot makers and affected stakeholders to dispell assumptions about the other and increase mutual awareness.

In the following, we present examples from REELER's cases where ethical issues emerged, from an ethnographic point of view, in relation to the decisions made in design and development. Through these examples, we justify the role of alignment experts by presenting how we think they could have made a difference in these cases by increasing human proximity between actors in the inner and outer circles of the Human Proximity Model. This will entail identifying the separate motives, acting as cultural brokers to build a common language, and aligning these motives by facilitating collaborative learning. However, we are also aware that our present-day education as ethnographers may not have equipped us sufficiently for understanding the wider issues of how our findings affect business models, economy and technical engineering.

12.1 Identified proximity gaps

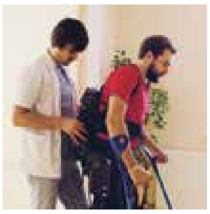
Across all eleven REELER cases, and the many robots represented in these cases, REELER identifies ethical and practical challenges occurring in the design and development stages, as well as during implementation of various robots. Here, we present a selection of these challenges to demonstrate the potential for involving alignment experts. Though some issues are tied to particular cases, many of the issues also go across cases (for instance the issue of normative understandings of end-user's body size and motives).

WIPER

WAREHOUSE

SPECTRUS

SANDY



REGAIN

Case	Problem	Role of alignment experts
WIPER	The technology repeats same mistakes as past technologies by not taking account of the workers' piece work situation. For the workers, time is more important to them than their own safety, therefore they will not use the robot if it is slow.	Observe the role of tools in the existing workflows of end-users and directly affected stakeholders, identify workers' motives (working quickly to earn a high piece rate), and thus foreseeing problems with the proposed solution. Save money by not repeating past mistakes.
WAREHOUSE	Task complexity is reduced by robotization, making already unappealing work even less engaging. There may be issues of sabotage of resistance. The work is more efficient and costumers can get their consumptions without human involvement. However, a lack of people may cause costumers frustration if something goes wrong.	Identify actual end-users (the few people left to operate robots), directly affected stakeholders (the few people left to work in the warehouse) and distantly affected stakeholders (who include costumers). Work on aligning motives to ensure the best result for all.
SPECTRUS	In hospitals, new automated robotic vehicles (e.g. delivering equipment or blood work) are shut off by patients or nurses, because they block elevators.	Identify end-users (e.g. nurses who benefit from not having to run after equipment) and directly affected stakeholders that are not intended as end-users and have their pathways blocked (patients, other nurses, e.g.) and take into consideration their training needs in the implementation phase.
	Implementation was complicated by differences in door types and worker body height in different regions and countries.	Investigate application sites with regard to physical environment in relation to culture.
SANDY	One robot, 15 years in development, could only work in very particular environments in Northern Europe, thus excluding other potential areas of application. Furthermore, it was developed in a place, where farmers where educated in the use of complex farming technology.	Identify different types of affected stakeholders who may benefit from a farming robot and help adjust the robot to other local needs (for instance small scale farmers in Africa). Identify affected stakeholders' need for re-education.
REGAIN	Overfitting to home layouts common to particular European regions hampered international dispersion. Furthermore, if the end-user is a patient, there is a tendency to overlook the nurses or physiotherapists as directly affected stakeholders, or a patients' partners', who would be involved in the patient's use of the robot at home (e.g. mounting a exoskeleton), in the development process.	Identify cultural integration challenges, like differences in environments (e.g. thresholds, tables, children's toys, pets). Identify directly affected stakeholders (e.g. nurses and/other patient's partner, e.g.) that might be essential to the robot's use – and help make a more inclusive design.

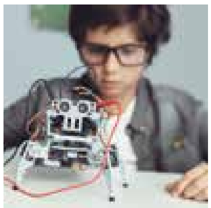

OTTO


HERBIE


COOP


COBOT


BUDDY


ATOM

Case	Problem	Role of alignment experts
OTTO	In this case the robot developers worked extensively directly with end-users. However, even here some issues arose because the robot was heavy and had to be re-assembled from parts. Working too closely with particular end-users may make them less likely to be outspoken and critical till it's too late.	Identify the 'real' motives for working on and with robots and help going beyond the working group to identify how a robot would work also when the project and attention to the workers is over. Too many robots are put aside after a while when implemented in everyday life.
HERBIE	Self-driving vehicles are often presented in unrealistic ways in public media. In reality they will involve a lot of adjustment on the part of the end-users, but also of all other affected stakeholders.	Help align expectations so both end-users (those in the car) and directly affected stakeholders (pedestrians, bicyclist) and distantly affected stakeholders (traffic planners) understand that self-driving cars are not intelligent in a human way and possibly will need a separate space to operate.
COOP	By focusing solely on effiency, companies run the risk of sabotage, when moving robots from cages to work lines. Also, the efficiency may counter other issues for instance climate change.	Help situate the need for higher effiency in a network of other needs, e.g. a meaningful worklife or a safe work environment. Help indentify motives for sabotage. Help identify needs for re-skilling.
COBOT	As robots are expected to work in close proximity to humans, new ethical and practical issues arise e.g. of workplace rhythms. Some concern sabotage, like in COOP, others the importance of having workplace colleagues, and feeling pride in your work.	Help identify specific end-user-robot interaction issues (such as humans being too slow or too fast). Help identify social issues, e.g. the how relationships between colleagues change and potential needs for re-skilling.
BUDDY	Humanoid robots are often presented in the media in ways that may be misleading. People automatically antropomorphize robots; e.g. thinking they have feelings, wants or needs.	Help identify and align imaginaries. Help the general public and politicians get a reality check on what robots really are and what they can do.
ATOM	Robot developers built a controller for children that could only fit adult-sized hands.	Help identify different bodily features of end-users, and explore a wider range of issues tied to end-users including how they learn to operate robots, and how robots' fit environments and are affordable.

While this list is not exhaustive, it exemplifies the diversity of the issues arising in the different robots across cases. We can see that there are conceptual and physical gaps between robot makers and affected stakeholders, related to robot makers' normative notions of users and stakeholders' lived experiences; between the ethics practiced by robot makers and the ethical concerns affected stakeholders' situations elicit; between rhetoric of relief and everyday work lives; between the robotic solutions proposed and the problems they are meant to solve; and between shared cultural conceptions of robots and real material engagements with robots. These gaps in normativity, ethics, relief, problem-solving and imaginaries are prevalent across cases and have real consequences for robot makers, for affected stakeholders, and for society. Through empirical case examples, we explore (in section 12.4) how alignment experts might bridge these gaps to facilitate collaborative learning between robot makers and affected stakeholders.

12.2 Bridging the gaps?

In the following, we look at some of the ethical gaps identified and discuss how, from our ethnographic perspective, alignment experts may have been helpful in bridging the gaps between robot makers and affected stakeholders. However, Non disclosure agreements (NDA's) keep us from providing explicit real world examples. Furthermore, while we often refer to specific case-studies where some topics were particularly salient, the issues most often go across cases (*see also Annex 1 Methods and Methodology*).[2] We also realize that robot developers may not always welcome our contributions as they may interfere with their work and increase costs.

In exploring the ethics as safety gap through the WAREHOUSE and COBOT cases, we show how alignment experts could contribute by identifying stakeholders and investigating motives of persons across the Human Proximity Model.

In exploring the normativity gap through the ATOM and REGAIN cases, we show how alignment experts could contribute by explicating situated cultural contexts and foreseeing 'unforeseen' problems.

In exploring the relief gap through the SPECTRUS and WIPER cases, we show how alignment experts could contribute by balancing stated aims with lived experiences and developing a common language between robot makers and affected stakeholders.

In exploring the problem-solving gap through the OTTO and SANDY cases, we show how alignment experts could contribute by distinguishing problems to be solved with robotics from those problems better solved by other means (e.g., policies).

And finally, in exploring the imaginaries gap through the HERBIE and BUDDY cases, we show how alignment experts could contribute by confronting cultural imaginaries with material experiences.

12.2.1 Ethics gap: identifying stakeholders and investigating motives

The WAREHOUSE and COBOT cases demonstrate a gap between a holistic approach needed for understanding ethics in an everyday warehouse setting and the narrow ethics-as-safety perceptions found in the inner circle (*see 4.0 Ethics Beyond Safety*). One of the findings from these cases is that robotization may be decreasing task complexity for warehouse and factory workers. Motivation matters for workers across all cases but is salient in the case of warehouses. Engagement is already a problem in warehouses to the extent that some warehouse managers employ strategies for maintaining a dynamic and changing workflow, by switching between 'wave' and 'batch' picking, and creating picking competitions to keep up worker motivation and productivity. Still, worker turnover is high.

> *A good worker should have a normal head on their shoulders and a willingness to work [laughs]. They're the two biggest skills that are required. And somebody who enjoys it. Somebody just putting in the hours is no good. You need a bit of 'get up and go'. I think they would have a section that they look after themselves. So that somebody can take pride in their work and try and make it look good.*
>
> (Brian, wholesale store owner, affected stakeholder, WAREHOUSE)

Meanwhile, emerging robotic solutions in logistics and manufacturing/production are often reducing task complexity. One particular robot used for shipyard welding was tasked with complicated welds, which, when performed manually by human workers, required more skill than ordinary welds and thus entailed higher compensation. Workers sabotaged this robot – presumably because it ruined their sense of pride in doing a good job. Similarly, software was introduced in a sheet-metal factory that diminished workers' task complexity and feeling of ownership by reducing their task from manually programming bending coordinates, to scanning a specification sheet and placing and removing the sheet metal from the machine. The software was abandoned after workers ignored the new feature and continued with manual inputs. In warehouses, a new robot would change the work so that workers no longer drove around, getting on and off of the vehicle to pick items, and talk to colleagues, but instead walked ahead of an automated cart to pick the item from the shelf and place it on the cart. The robot's developer presented this simplification at a robotics conference in Europe as a benefit to the human. In

2 see responsiblerobotics.eu/annex-1

REELER, however, we have seen that human workers require more agency and complexity in their work for both satisfaction and productivity (*see also 10.0 Meaningful Work*).

In the WAREHOUSE and COBOT cases, REELER researchers interviewed participants inside and outside of the robotic inner circle. In speaking with warehouse and factory workers meant to operate robots (i.e., the real end-users), we found out what mattered to them, in their workflows and in relation to robotization. Talking with their managers (i.e., directly affected stakeholders and spokespersons) led to more insight into the challenging decisions SME owners face in balancing productivity needs with worker satisfaction. Involving recruiters and union representatives (i.e., distantly affected stakeholders) brought a broader perspective to the skills and employment challenges that robotization might bring to the sector. Finally, interviews with CEOs, engineers, and salespersons (i.e., robot makers) led to the realization that developers of warehouse logistics and manufacturing solutions are primarily focused on productivity (increasing efficiency and solving staffing problems), but less so on the problems or needs of the workers. While not within the scope of the REELER project itself, this case demonstrates the potential of alignment experts in identifying stakeholders across the Human Proximity Model, and in investigating the motives and values of each.

12.2.2 Normativity gap: filling in situated cultural contexts and foreseeing 'unforeseen' problems

In exploring the normativity gap through the ATOM and REGAIN cases, we show how alignment experts could contribute by presenting situated cultural contexts and foreseeing 'unforeseen' problems. Normativity is as argued in *5.0 Inclusive Design*, a lack of awareness of others' bodies, experiences, or life worlds. In the ATOM case, the developers were surprised by the much smaller hand size of their actual end-users. A necessary adjustment was thus made to fit the size of children's hands. In the REGAIN case, developers of one robot ran into problems because the robot's language was culturally inappropriate (i.e., too harsh) when transferred from the country of development to another country for implementation. Alignment experts would help with an attentiveness to nuanced cultural barriers and an ability to traverse them.

12.2.3 Relief gap: weighing rhetoric with lived experiences and developing a common language

In exploring the relief gap through the SPECTRUS and WIPER cases, we show how alignment experts could contribute by balancing stated aims with lived experiences and developing a common language between robot makers and affected stakeholders. When the explicit motive of robot makers is to relieve workers of menial work, heavy lifts etc. they should know how works experience these issues before the make a robot that is meant to be a relief. In the SPECTRUS and WIPER cases, we have seen how work is talked about and perceived differently by robot makers and affected stakeholders. Here, alignment experts could help develop a common language, around manual labor, e.g., that is not so unevenly value-laden (e.g., menial, tedious). Conceptualizations are very distant from lived experiences.

12.2.4 Problem-solving gap: distinguishing problems to be solved with robotics from those problems better solved by other means

In exploring the problem-solving gap through the OTTO and SANDY cases, we can discuss how problems are identified and by whom robot development is initiated. Alignment experts could contribute by distinguishing problems to be solved with robotics working closely with end-users (OTTO) from those problems better solved by other means (SANDY). They could also help finding a wider group of stakeholders in need of the robot developed if the problems were formulated in slightly different ways (SANDY). For instance, the problem of making a good harvesting robot could be connected to both big, linear farming environments and small, curvy farming areas. This may even benefit small farmers in Africa if this type of small, agile farming robots were developed (*see Annex 5 REELER Outreach tools* [3] and the REELER homepage for debates on these issues in our MiniPublic at Hohenheim University).

12.2.5 Imaginaries gap: confronting cultural imaginaries with material experiences

Across all cases we find gaps in how robot makers (including developers), affected stakeholders and policy makers imagine robots. Alignment experts could help in providing reality checks to public media and policymakers, and they could help application experts (who for instance 'sell' robots in public media) depict robots more realistically (but equally appealing). In exploring the imaginaries gaps around self-driving cars and humanoid robots in the HERBIE and BUDDY cases, alignment experts could contribute by contrasting cultural imaginaries with material experiences; not least in relation to the concepts tied to robots such as 'autonomous' and how humans need to change to adapt to robots (*see 8.0 Imaginaries and 4.0 Ethics Beyond Safety*).

12.3 Increasing human proximity and identifying motives

If these human proximity gaps are problematic for robot makers, and if collaboration might solve these problems, it seems obvious that robot makers should address the gaps in their own by collaborating with affected stakeholders. In fact, REELER began with the hypothesis that increased collaboration might solve some of the ethical challenges in design. However, we found that robot makers find it challenging to address these identified proximity gaps on their own. First of all, there are many structural, economic and social issues that

3 see responsiblerobotics.eu/annex-5

make it difficult for them to collaborate directly with end-users and affected stakeholders.

1. **Resources**. It is very time consuming (and thus expensive) to collaborate with people with whom you do not share common language or motives. It takes time to recruit participants, to help them to understand the proposed project, and to become familiar with their everyday work.

2. **Distributed development**. Robot development is often distributed, both geographically and in terms of tasks. One person or organization might be responsible for developing the user interface while another works on movement and navigation. It is unclear who should be responsible for collaborating with the end-users and affected stakeholders.

3. **Access**. Legal/regulatory and practical limitations may also impede access to real-sites during development. Many safety and occupational hazard regulations inhibit testing of prototypes in workplace settings. Further, many affected stakeholders do not have the agency to participate in development processes related to their work, which often leads instead to spokespersons (management) being involved.

4. **Changes**. Sometimes, the involvement of end-users may precipitate changes which complicate the development process. If an end-user's experiences disrupt the normative perceptions of use/users, they may necessitate costly or time-consuming changes to the robot's design. This is especially true of robots beginning from familiar technologies, applications, and collaborations.

5. **Disciplinary blinders**. Robot makers often do not recognize affected stakeholders as relevant to the development process. Moreover, the end-users that are identified as relevant are often used instrumentally as testers as it can be difficult to step outside one's own experiences to recognize the potential contributions that end-users and affected stakeholders can offer.

6. **Relational expertise**. Even if robot makers do engage with end-users and more distantly affected stakeholders, it can be difficult to find out what matters to them – and how to extract what really matters across a group of diverse end-users that all come up with different ideas. Without sufficient relational expertise, collaboration remains cooperation without any alignment of motives.

Core expertise: *The skillset and knowledge base one has developed through education and/or experience.*

REELER's findings show that problems often arise in development because of these six challenges in collaboration. In the ATOM case, for example, a social robot was designed for consumer use. The robot developers demonstrated very proficient skills in collaborating. They collaborated effectively with persons within the robotic inner circle with proximal **core expertise** – that is, a skillset and knowledge base born out of similar disciplinary backgrounds and experiences. They worked with a design company for the robot's aesthetic design and with another company to develop story content for the robot. Furthermore, they collaborated with and learned from persons outside of the inner circle with more distant core expertise, including investors, public institutions, media people, but also potential consumers (school children) and local experts (teachers).

Even in this best of cases, the developers ran into trouble in leaving their technical comfort zone and venturing into the unknown land of other people's everyday lives. The robot project started with product-oriented beginnings, from familiar technologies and familiar collaborators. It did not start with a clearly defined problem (i.e., how to teach kids programming skills) and did not involve calling in experts for how this best could be done. Although the robot developers were able to effectively collaborate with persons across disciplines, they did not fully exploit their engagements with persons whose core expertise was farther from their own. They, like in a couple of other cases (REGAIN, WIPER e.g.) really tried to involve teachers but as education was a new field to them, they did not fully capitalize on teachers' expertise in knowing how difficult it is to teach.

Thus, even the best of efforts by robot developers might not be enough -- and perhaps it is not within their ability (or responsibility) to close these gaps on their own. Often, robot developers themselves make user studies, but they are not educated to understand the motives and everyday concerns of the affected stakeholders. Here, the robot developer Valdemar explains the group behavior of workers, they (the developers) have studied (but not collaborated with directly) to develop their robot.

> *I think it's a mix of workplace culture and the physical requirements of the job. I think it stems from, well, try chopping firewood; once you've chopped for 15 minutes, you'll need a break too. There's also what you might call an old-fashioned style; they smoke a lot, these people. It's one of the few places where I meet a lot of smokers. They need a break for smoking, and a break for coffee, and there's no question about that. It's no business of mine, but it's quite obvious they take their time to fiddle with various things. Some of them don't say anything during these breaks, others have all sorts of more or less insightful comments about what a poor job the people that came before them had been doing. You should try asking a psychologist about these issues, maybe they know more about it than the anthropologists. But it's a common theme. It's always very apparent that they stick together in groups; there might be people from other companies [they engage with], but not much.*
>
> (Valdemar, engineer and CEO, robot developer, WIPER)

Valdemar does not (as social scientists are trained to do) get an insight into how these workers would consider their robot once implemented. He gets some indications of how they will be annoyed when routines are changes, but not really how and why. These findings were, however, elicited by REELER researchers who gained insight into what motivates people to sabotage robots.

One of the reasons for this difficulty in understanding each other comes from the robot developers and affected stakeholders having very different core expertises and very different life worlds. Often robot developers see the humans affected by their robots as very far from their own (and our) communities – and have difficulties taking their perspectives and understanding their motives. They recognize that many of the people who are to work in the closest proximity of the robot may not be educated as engineers, but they also lack a sense of how these people may have other types of core expertises that matter.

Yeah, yeah. It's tested on people, yes. Or basically, on real people that work in the warehouse. And you can even understand the way they speak, the way they [live] is slightly different than yours and my roles. So, they are simple people, let's put it this way.

(Felix, CEO advisor, robot maker, WAREHOUSE)

Indeed, affected stakeholders who are exposed to robots sometimes feel their core expertise has not been seen or respected by robot developers:

Interviewer: "Do you think they know about your life?"

Anita: "Sometimes they don't. The people who [develop robots], before they start doing that, they need to go to the places where we work to see what kind of work a human can do. And then they have the responsibility to do good things but sometimes I think that they think 'They [the cleaning staff] do that, but they don't know exactly what the job is'."

(Anita, hospital cleaning staff, affected stakeholder, SPECTRUS)

Relational expertise: *A capacity to recognize the motives of those with different core expertise, to understand the value of their expertise, and to mutually align motives in joint work.*

Although robot developers sometimes formed particular ideas about end-users as a group, they seldom considered themselves and their developer peers as belonging to a collective culture. Collaborative learning is ideally a process of mutual learning that depends on collaborators being motivated to break out of their individual bubbles. However, to recognize and respect their own and the affected stakeholders' different roles in collaboration requires what the educational psychologist Anne Edwards calls relational expertise. Edwards defines relational expertise as "a matter of recognizing what others can offer a shared enterprise and why they offer it; and being able to work with what others offer while also making visible and accessible what matters for you" (Edwards 2010, 26). REELER defines **relational expertise** as the capacity to recognize the motives of those with different core expertise, to understand the value of their expertise, and to mutually align motives in joint work. Here, alignment experts could act as intermediaries, helping robot developers to recognize their own culture and how, e.g., this culture frames their interpretation of affected stakeholders' needs and motives.

If collaborative learning is to align these *different* groups working towards a common goal, it is necessary to find out what motivated them to begin the collaboration at all. In REELER, we find the best way to define collaborative learning is how one learns to understand what motivates others through an expanded skill of relational expertise, and to communicate these motives to the collaborators so that they might align themselves in working together toward a common goal. Relational expertise is a capacity to work relationally with others on complex problems. It involves knowing how to know who can help. Knowing how to know who is a capability that can be broken down into being able (i) to recognize the standpoints and motives of those who inhabit other practices and (ii) to mutually align motives in joint work. Relational expertise is therefore another form of expertise one can develop in addition to their own core expertise (often tied to one's education/occupation) and makes fluid and responsive collaborations possible.

A basic premise of Edwards' work is that collaborators need to exercise both a core expertise (in one's discipline or work, e.g.) as well as a relational expertise in learning what matters to others when they work together. One example, used by Edwards, is when teachers, psychologists, housing specialists and social workers with different motivations are engaged in helping a vulnerable child. The teacher has a core expertise in helping the child learn in school; while the social worker will focus on the child's family. The educational psychologist and housing specialists will also have their motivated ideas of how the child may be helped. Together they constitute a group engaged in the same problem space, helping the vulnerable child, without being reduced to nodes in a system. They

An alignment expert would act as a cultural brokerage, mediating between groups or persons with different values, understandings, and motives.

are in Edwards' words: "likely to interpret the developmental trajectory of a vulnerable child in slightly different ways because they are located within different practices where the motives for engagement with objects of activity are also different" (Edwards 2010, 7).

Just as the robot developers today learn from funding agencies about their motives (often codified as strategies) in order to apply for funding, and funding agencies learn from robot developers what their technologies are capable of (*see 2.0 Robot Beginnings* and *3.0 Collaborations in the Inner Circle*),[4] so the robot developers could learn from the affected stakeholders about how robots could relieve and improve their everyday lives. The affected stakeholders could, in turn, learn from robot makers what robots really are (rather than relying on public media to convey information about robots).

As described above, many factors make it difficult to exercise relational expertise in practice. This was particularly true in REELER's cases when collaborators' core expertise was very dissimilar (like cleaning and robotics, for example). We propose that alignment experts might be capable of doing this bridging work for the robot developers and affected stakeholders. This alignment task would involve spanning the space between the robot makers' communities of practice and the affected stakeholders' communities of practice to identify their separate motives, and to communicate them to one another in a move toward alignment and collaborative learning.

12.4 Building common language through cultural brokerage

What does it mean to align?

A person's perspectives and engagements with the world are framed by their socio-material worlds, where each is composed of their disciplinary backgrounds, their past experiences, their current material and temporal settings. When they enter a shared problem space, they may be interpreting the problem differently. Without translation, collaborators may be working toward the same shared goal (robot development, e.g.) without recognizing each other's motives.

Alignment experts can draw out these different motives by studying *with* different groups. By drawing on traditions in anthropology, they can mediate between groups or persons with different values, understandings, and motives – effectively acting as *cultural brokers*. Medical anthropologist Mary Ann Jezewski defines **cultural brokerage** as *"The act of bridging, linking, or mediating between groups or persons of differing*

4 To be found in the online version of *Perspectives on Robots* – see www.responsiblerobotics.eu

cultural systems for the purpose of reducing conflict or producing change" (Jezewski 1995, 20). In REELER, the change we aim to produce is to increase human proximity and promote relational expertise.

> **Cultural brokerage:** *Translating motives, values, and understandings between persons with different cultures and disciplines to increase human proximity and promote relational expertise.*

In bridging these different socio-material worlds, and making each group more aware of the other's motives, values, and understandings, alignment experts can help the groups to build up their own relational expertise. The REELER project has developed some experimental tools for facilitating this learning between groups. Many of these tools involve perspective taking. These tools for collaboration have been tested in REELER with good results and show promise, but are nevertheless still experimental (*see Annex 5 REELER Outreach Tools*).[5]

1. **BuildBot** is a board game that was developed out of interdisciplinary collaboration between REELER's robot developers and anthropologists, using data from ethnographic interviews to simulate a reflective robot design process. In this game, players take on the role of robot developer designing a healthcare robot. The players must manage their resources in interviewing different stakeholder types (patients, care providers, unions, policymakers, e.g.) and spending money on developing robot features. The game includes stakeholder statements from the real REELER case studies. These statements give robot developers some insights into the concerns and needs of others. The game involves a dialogue between players where they can explain their interpretation and consideration of stakeholder statements in the selection of robot features. Players are rewarded for selecting features that best match stakeholder needs. This game raises awareness about the complexity of a robot's context and expands development considerations beyond the inner circle to take in perspectives across the human proximity model.

2. **Social drama** is perspective-taking method developed in REELER, with inspiration from Sociodrama, a method used with groups in psychology and sociology. Social drama entails the creation of use scenarios around an envisioned robot enacted in an improvisational way. Participants take on dual roles in the sketches, performing a character role with an underlying conceptual role. For example, an eldercare robot scenario might include a participant acting as the robot, while representing the perceptions and concerns of a robot developer, while another participant acts as the elderly person representing concerns centering around the concept 'dignity'. Another participant might act as the elderly person's family member, bringing forth concerns around the concept of 'human development'. As the participants enact their scenarios, they embody these concepts to elicit different perspectives around the same situation. In this way, the scenario is a perspective-taking exercise that shows how relational expertise is necessary to understanding the plurality of motives, values, and understandings when different sociomaterial worlds meet in collaboration.

3. **Mini-Public** is an established debate forum method intended for democratic participation in decision-making. In REELER, we have adapted the Mini-Public for use by alignment experts as facilitators of dialogue between groups with asymmetrical power relations. Specifically, we have used the Mini-Publics to give voice to affected stakeholders in conversation with policymakers and experts in specific sectors or fields of robotics. The Mini-Public has three components: expert presentations, democratic participation (e.g., polling), and deliberation. REELER has tested various forms of democratic participation techniques including analog and digital methods like the interactive presentation software Mentimeter. [6] After listening to the expert presentations, participants have the opportunity to voice their opinions through anonymous polling or voting. Then, the results are shared and the experts and citizens engage together in critical discussions. After some deliberation, the polling and voting is repeated to measure how/whether the participants and experts have learned from taking in different perspectives in the interdisciplinary/cross-cultural exercise.

All of these tools are meant to increase human proximity and build up a competency in finding out what matters to the persons one collaborates with. In doing so, one can become aware of their *relational responsibility*. A robot developer might, for instance, better understand the effect of their decisions on an affected stakeholder. Such an understanding comes with a responsibility to mitigate any potentially negative effects (*see 4.0 Ethics Beyond Safety*).

> **Common language:** *A common ground of mutual understanding, knowledge, beliefs, assumptions, pre-suppositions, etc.*

However, even the best of tools cannot by themselves handle the process of cultural brokerage. To progress from perspective-taking to true collaborative learning, the groups would need to develop a **common language**, a common ground of mutual understanding, knowledge, beliefs, assumptions, pre-suppositions, etc., which is necessary for many aspects of communication and collaboration (e.g. Edwards, 2005, 2010, 2012; Baker et al. 1999). However, it has been clear from the REELER data presented in the previous chapters, that developing this common ground is *not* easy.[7] In working towards a common goal, the collabo-

5 see responsiblerobotics.eu/annex-5

6 https://www.mentimeter.com/

7 See Annex 1 Methods and Methodology: responsiblerobotics.eu/annex-1

rators will need to gradually align (but never conflate) initially different motives and expectations.

In order to collaborate today, robot makers have to align not just the material output (the goal of making a physical robot) but also the motives behind the material output with those of affected stakeholders – in this case an alignment of what is meant by a responsible and ethical robot.

"Through the negotiation of goals, agents do not only develop shared goals, but they also become mutually aware of their shared goals" (Dillenbourg 1999, 8). And a general call for researchers to reach out of their own normativity bubbles to expand their knowledge:

"Experts must now extend their knowledge, not simply to be an extension of what they know in their specialist field, but to consist of building links and trying to integrate what they know with what others want to, or should know and do." (Nowotny 2003: 155)

We also see examples in the REELER data that robot-makers themselves are aware of the importance of working together with the people expected to use the robots to make robots that are accepted in the end:

> *And even in the complete service robotic community, this is a new goal. Because there are many projects focusing how to solve technical problems. But one of the biggest problems is, even if you solve [the technical issues, that], no one will use it. Because the robot is not accepted. So, you need to bring everything together*
>
> (Thomas, engineer working on a humanoid service robot, robot developer COBOT)

Thus, the definition we propose for collaborative learning that results in responsible ethical robotics is that collaborative learning is: A process of alignment of different motives and expectations in working toward a common goal.

Specific to robotics, collaborative learning is a process that over time aligns the motives and expectations of robot makers with the motives and expectations of users and affected stakeholders to ensure the creation of the best possible ethical and responsible robotics.

Following Edwards work and combining it with our REELER material, we suggest a new definition for collaborative learning that can be used by alignment experts.

Collaborative learning begins with an identification followed by an alignment of robot makers' and affected stakeholders' motives, when enough common ground is obtained to initiate collaboration (working together) toward a common goal, with these motives in mind.

Robot developers cannot be expected to be experts in how to get to know affected stakeholders and their underlying motives for using or rejecting a robot. This is why we propose a new education to help develop the skills needed to understand the motives and core expertise of both affected stakeholder and robot makers, and cultivate the core expertise, which makes an alignment expert.

Our definition places the responsibility for learning about each other on both robot makers and affected stakeholders/users but with the help of alignment experts. Whereas material goals may be explicated in a collaborative process, we take it that robot makers and affected stakeholders should also explicate their motives for designing and/or using or not using a robot to the alignment experts. There is, however, a built-in asymmetry as this collaborative learning is most likely to be initiated by the robot makers, as affected stakeholders in general know very little about the robots being developed for and around them – and have limited or no access to robot makers and their work.

This concept of collaborative learning has two parts: it is about doing something together, but it is also about learning from each other while you do something together. Collaborative learning describes the situation where people not only attempt to learn from each other, but do so with the aim of collaborating. And they aim to collaborate to learn from each other. Collaborative learning is ideally a reciprocal affair. However, as we have seen throughout the chapters, when we move outside of the inner circle collaborations do not begin with two equal partners learning from each other. In the inner circle the participants have for many years build up common motives and a common language. When they move outside of the circle, they need help from alignment experts to collaborate with (and in some cases even identify) end-users, directly and affected stakeholders, understanding their motives and language.

REELER findings show that the robot makers' design processes, and their community in general, can benefit from a raised awareness of why and how collaboration with end-users, direct and distant affected stakeholders can be a valuable contribution to existing design processes. It will improve the chance of making responsible and ethical robots, because a closer collaboration will give access to valuable everyday life experience.

From the REELER data presented in the previous chapters we see a potential not just for more ethical and responsible robotics, but also for robot makers to cultivate new ideas through a raised awareness of how affected stakeholders could be included in design processes in a lucrative way. As noted, it is difficult to live up the 'holistic' approach presented as the way forward by some robot developers – where inclusive thinking is realized by observing and working with users, where you get to be *"part of their ethic, like, their world"* as it is phrased by one of the robot developers (Elias, robot developer, engineer at the Northern Techno university) (*see also 4.0 Ethics Beyond Safety and 5.0 Inclusive Design*).

Affected stakeholders often worry about how it will be to collaborate with robots, but the reality may prove to be entirely different (*see 8.0 Imaginaries*). We also acknowledge that both ethnographers and affected stakeholders may know too little about business models and technical issues prevalent in the inner circle. However, an awareness of how affected stakeholders view robots may also lead to new ideas. During fieldwork, the ethnographers have observed many areas where people could use robots in their daily lives which have not been developed yet (help to clean houses with many stairs and spider web in the ceiling e.g.). True collaboration with end-users may also ensure that the robot design becomes more inclusive and accepted.

Finally, alignment experts may help identify all the many people around the envisioned end-users, who could also be involved in the design process (e.g. co-workers or relatives to people using exoskeletons), as they will also be directly affected by the robot (and may sabotage or reject it) without being considered end-users.

12.5 Concluding remarks on Human Proximity

Collaborative learning was chosen as a key concept for the REELER project because our main hypothesis was that robot makers need new tools to improve their knowledge of and collaboration with users and affected stakeholders, in order to improve the creation of responsible and ethical robotics in Europe. This is partly due to the robots coming out of their protective cages in industrial settings and directly engaging with people in their everyday lives, partly because robots (combined with AI) are changing the lives and work for most of the European population with the present development of robotics in new fields.

Also, the robot makers themselves begin to see the need to expand their collaborations and increase their awareness. We acknowledge that it is probably not possible to work directly with the most distantly affected stakeholders, but we will carefully suggest that robot makers and robots can benefit ethically and financially when these collaborations occur. Collaboration is a process where you develop something together – and collaborative learning is, in REELER's definition, a matter of aligning motives. In the REELER project, we have developed some experimental tools and suggestions for how robot makers can confront their own normativity and increase their proximity to affected stakeholders and potential end-users, to get to know more about their motives through collaboration with social scientist intermediaries called *alignment experts*.

Thus, REELER proposes a holistic approach to robot ethics that centers on collaboration across the Human Proximity Model, facilitated by alignment experts – rather than the spokespersons and application experts already operating in robotics. Alignment experts differ from spokespersons because they *research* who they 'speak for'. Today, what we define as spokespersons are, for instance, managers who speak on behalf of workers but this does not ensure managers know about everyday problems from a worker's perspective. Application experts work on special local issues (for instance a designer or psychologist who knows what colors work best in a design of robot appearance). Their task is not to see the more holistic aspects of how end-users and directly/distantly affected stakeholders work with robots.

We readily acknowledge that we currently lack an education which combines relational expertise and cultural brokerage with an understanding of business models and technical details. An education which fosters expertise in alignment methods used to study situated practices and cultural phenomena combined with communications training for interdisciplinary collaborations. Newly educated alignment experts could be tasked with identifying proximity gaps and relevant actors. Next, they could work on actual collaborations practicing and advancing the experimental methods of perspective taking (BuildBot, social drama, e.g.) that REELER has developed for building relational expertise. By identifying and communicating the motives across the Human Proximity Model, alignment experts will help robot makers develop a common language with affected stakeholders and will make robot makers aware of their relational responsibility to affected stakeholders. However, their education also needs to emphasis the importance of time, money and market issues that matter for robot developers. In this way, alignment experts may act as intermediaries to draw together affected stakeholders from the periphery and robot makers from the center of development to increase human proximity, expand the locus of decision-making, and initiate collaborative learning for more responsible and ethical robotics in society as a whole.

(Photo by Kate Davis)

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I think a very, very important issue clearly is to have, in every large project, people from an interdisciplinary background because that's the way for problems [to get solved] which necessarily involve a human part, and a technological part. To get at least some idea of what to expect and foresee, you need people from really different areas.

(Jorge, head of research lab, robot maker, BUDDY)

13. Conclusion

What kind of future do we want to create with robots and artificial intelligence?

We are at the climax of the great grand narrative of technology. This narrative tells a story of constant progress and of robot technology relieving people of hard work, giving us free time to develop ourselves through meaningful tasks and new interesting work. As a whole, the development of innovative robot technology is not only necessary, but can also be a blessing for a society. However in order to create the future we want, we also need a story of pitfalls and realistic scenarios of how we can and ought to deal with robots and AI (artificial intelligence). In other words, we need a reality check on the narrative, on the storytellers - the robot makers, as well as the listeners - the affected stakeholders.

Human culture has always been defined by material tools. What may be different this time is that these tools, robots and AI, are developed in somewhat closed environments far from the realities where these technologies are going to be put to use. Furthermore the new type of innovative robots developed today, and studied by REELER, have moved from factories into the lives of people in hospitals, schools, construction sites, public streets and homes. This move calls for a new awareness of the ethical responsibilities that follow from robots engaging and entangling with people in their everyday life settings.

The protagonists of the grand narrative of technology can no longer just be developers, funding agencies and other robot makers but must include the end-users, as well as the overlooked directly and distantly affected stakeholders. *Perspectives on Robots* introduces new voices and serves as a reality check on imagined futures. Our research has focused on what we can do better to create ethical robots and AI that fit the different life-worlds of affected stakeholders.

In REELER we have undertaken one of the most comprehensive ethnographic studies of robotics in Europe ever. Our analysis runs across 11 cases, each representing a different type of robot and covering many sectors. We set out to explore general gaps between robot makers and affected stakeholders, scrutinize consequences of these, and develop new approaches to bridge them. We have presented these explorations in the previous chapters of *Perspectives on Robots*, as well as on the REELER Roadmap homepage (*www.responsiblerobotics.eu*), where it is also possible to access this publication's supplementary material [1] and the Online Interactive Toolbox (*www.responsiblerobotics.eu/toolbox*).

The fact that there are gaps between the realities of robot makers and affected stakeholders has been documented across the 11 cases in REELER.

The initial aim of our research work was to develop research-based tools to make robot developments more ethical and robot makers (i.e. robot developers/engineers, application experts, spokespersons and facilitators) more aware of affected stakeholders' needs. To accomplish this aim, the REELER Roadmap presents a two-pronged strategy for the future, which we propose to the European Commission.

1. Develop and disseminate tools that enhance *robot developers'* (engineers, mostly) awareness of what is to be gained from collaborating with and taking end-users and affected stakeholders' perspectives into account early on in the development phase.

2. Develop alignment experts as a new profession, where people are educated in methods of aligning view and visions of robot makers and, often unheard, affected stakeholders. Alignment experts can also give voice to distantly affected stakeholders, when relevant.[2]

This conclusion will summarize all the chapters in the full, online, version of *Perspectives on Robots*, including the three chapters *2.0 Robot Beginnings, 3.0 Collaboration in the Inner Circle* and *11.0 Gender Matters*, which are not included in the body of text in the printed version of the publication.

Perspectives on Robots consists of three parts:

1 Annex 1: REELER methodology. Annex 2: Excerpts from REELER's ethnographic data.

2 If alignment experts are to have real impact, the inner circle of robotics have to be convinced of their utility.

13.1 Summarizing Part One: Introducing the inner circle of robotics

1.0 Introduction, 2.0 Robot Beginnings, and *3.0 Collaboration in the Inner Circle*

In the early phases of our ethnographic fieldwork, REELER find that robot development is often distributed across different actors and organizations, and the person buying the robot may not be the same person using, encountering, and being affected by it. In response to this fact, REELER has developed a new vocabulary presented with the Human Proximity Model in *1.0 Introduction* as well as in *2.0 Robot Beginnings* and *3.0 Collaboration in the Inner Circle*.[3] The Human Proximity Model identifies different interest groups that either collaborate with, and learn from, each other or do not collaborate and learn from each other. Collaborations, or lack thereof, ethical consequences unfolded in PART TWO, which addresses robot developer's relational responsibilities. The HPM and its accompanying vocabulary opens the door to analytical discussions of the gaps REELER explore, and to new discussions of ethics regarding relational responsibility that will help ensure that robot makers conceive of and create more ethical robots.

13.2 Summarizing Part Two: Enhancing robot developer's awareness of affected stakeholders

4.0 Ethics Beyond Safety, 5.0 Inclusive Design, 6.0 Innovation Economics, and *7.0 Learning in Practice.*

Throughout our analysis we find that robot developers, who have generously shared with us their work and concerns for the past three years, care deeply about the quality of their robots, and are genuinely concerned with developing the best possible robot solutions. While many have little formal knowledge of ethics (*see 4.0 Ethics Beyond Safety*), they are often both interested in and care for the users of their robots. The majority of developers either work directly with end-users or listen to spokespersons and application experts speaking for end-users. In our general conversations and fieldworks, we see that developers are a very diverse group. In this diverse group, we also see some developers being less preoccupied with concerns for humans in their work. Here, humans and robots can be seen as dichotomies which involves choosing robots over humans, rather than combining the two.

Some robot developers also perceive robot buyers (who may never use the robot themselves) as end-users (who do use the robot) and many do not consider the potential added value of including directly affected stakeholders in their design work. Further, we see that directly affected stakeholders, as well as distantly affected stakeholders, are rarely given a voice in the activities and decisions taken in the inner circle of robotics. Thus, we conclude there is a need for this new vocabulary addressing ethics in terms of *relational responsibility* between robot makers and affected stakeholders. It is important to underline that this responsibility is not just a relation between end-users and robot developers, but involves all of the persons in the inner circle who are responsible for legislation and funding as well as all affected stakeholders. However, as there is also a clear power imbalance between these groups, we see the need for alignment experts to help giving voice to the affected stakeholders and translate their views into useful inputs in the debate.

5.0 Inclusive Design exemplifies some of the ethical issues arising from the closed collaborations, when affected stakeholders are not part of the group of collaborators and wider development decisions, and it suggests the need for new, grounded ways of thinking about users in relation to robots. This may, for instance, mean including consideration for not just end-users (like patients) but also directly affected stakeholders (like staff in a hospital) in decision-making processes. *6.0 Innovation Economics* discusses the importance of collaboration for innovation economics systems, which comprises multiple actors engaging in situated everyday practices to bring technological breakthroughs from the research laboratory to the market. Modern innovation economics distances itself from any linear, hierarchical, deterministic view. Rather, it frames technology development as taking place by knowledge-based collaborations of heterogeneous networks of entrepreneurs, research institutes, government, pressure groups, and other types of economic actors. Such innovation networks evolve endogenously over time, with autonomous actors entering, refocusing, and exiting, hereby also driven by emergence, maturation, transformation, and dissolution of their industries, etc. This understanding situates technological development within the social relations and activities of persons and organizations.

Likewise, *7.0 Learning in Practice* argues that by developing new ways of thinking and pursuing different, more *situated*, ways of knowing through education and through learning in situ (about users and robots in context), robot developers and affected stakeholders can achieve closer mutual proximity, and become much more aware of each other's sociomaterial worlds.

In all, Part Two points to how existing familiar collaborations, and the lack of stakeholder collaborations, can lead to exclusionary development processes – which may also hamper innovation as developers do not reap the full potential of including other perspectives in their design processes. In order to overcome this gap, we argue that robot developers may benefit from a relational expertise; learning what matters to others in collaboration toward a shared goal.

REELER has developed a number of experimental tools for exercising these perspective-taking skills. To help develop relational expertise in identified end-user/robot developer relations, we suggest both educational tools and the help from alignment experts. These may also help ensure that

3 Due to lack of space, we have not included these two chapters in the printed version of this text, but they can be found in the internet version.

Robot makers have the opportunity to craft a richer, more inclusive chapter on robotics in the grand narrative of technological progress. (Photo by Kate Davis)

the proper end-users and directly affected stakeholders are identified in the design process.

Thus, in part two we conclude that robot developers have a lot to gain from learning from end-users and affected stakeholders (possibly with the help of alignment experts). This awareness may be a road to more ethical and responsible learning in robotics that will hopefully lead to new and more productive innovation processes.

Some of the steps REELER argue are needed to better bridge the gap between affected stakeholders and robot makers fall, in some respects, outside the scope and responsibility of robot developers. This is most certainly the case when we look at the consequences for the broader group of distantly affected stakeholders, which part three zooms in on.

13.3 Summarizing Part Three: Expanding beyond the inner circle

8.0 Imaginaries, 9.0 Robotization of Work, 10.0 Meaningful Work, 11.0 Gender Matters, 12.0 Human Proximity, and *13.0 Conclusion.*

Not only robot developers can benefit from increased awareness of their relational responsibility. The REELER research show how robots will, and already do, affect society as a whole. In *8.0 Imaginaries*, we see that the way robots are represented by robot makers and application experts taps into a wider issue of how representations of robots in popular and news media affect the public, including policymakers. Here REELER calls for a reality check. Imagery of human-like 'intelligent' and 'autonomous' robots has ethical implications, as this imagery affects how European societies and politicians envision their robotic future. Chapter *9.0 Economics of Robotization* presents a large-scale discussion of the future of work, specifically addressing the expected economic impact of robotization including broad sectoral changes in employment. These impacts move far beyond the individual robot developer's or even the robot companies' ethical responsibility. Generally speaking, alignment between how robots are imagined in society and what robots can actually do is needed.

In *10.0 Meaningful Work*, we engage in a close-up discussion of the many qualitative transformations of work that robotization entails, sometimes with acknowledged benefits, other times resulting in an overall degradation of meaningful work. This chapter calls up contrasts between the values held by workers and the values inherent to the robotization of human labor. It points to a cultural gap that extends beyond robot developers to other robot makers and affected stakeholders, including employers, policymakers, labor unions, and educational institutions. Another matter which reaches beyond the responsibility and ability of the individual robot developer is the insular environments of technological developments. The fact that technological developments, like robots, are mainly driven by men with particular backgrounds and experiences, while the effects of these developments are felt by all is taken up in *11.0 Gender Matters*. In this chapter, we also present issues of gender in design and robotics/engineering culture which, if left unchecked, may contribute to an inequitably gendered society.

REELER suggests, in Chapter *12.0 Human Proximity*, a new education of alignment experts who can help confront the above-mentioned challenges. Alignments experts could supplement the relational expertise of robot makers to ensure that affected stakeholders also take responsibility for their role in the situated implementation of robots.

As argued in these chapters, the robot makers, including many robot developers, write scripts without having a clear idea of who the end-users will be who are in the closest proximity to the robots in everyday work. Furthermore, the directly affected stakeholders are often not considered in these stories. They are, for instance, the nurses, the physiotherapists, the car mechanics or the school teachers, who will not be users of robots helping patients, driving cars or teaching math, but they will still need to accommodate and help implement the robots. The robot developers have a hard time understanding the messy social and material environments where their robots are to work, as their stories are often (if at all considered) written for neat and clean 'mock-ups' far from the reality on the shop-floor. And though it is not the responsibility of robot developers to ensure that distantly affected stakeholders get a new meaningful job or education (like fruit-pickers losing their job to a robot, or secretaries in need of reskilling), it could be seen as an overlooked responsibility of other robot makers (such as funding agencies and policymakers). All of these new ethical responsibilities also come with a need for someone to consider the long term potential positive and negative effects of the expensive robots developed: whether the robot is welcomed after a while of scepticism, or the innovation investment is lost because the robot is mothballed or sabotaged, or because, in a long term perspective, the robot changes environments in undesirable ways.

All story-telling is normative. As emphasised by innovation economy we need heterogeneity to ensure innovation. We need new voices in the narrative – and at the same time a more comprehensive and holistic view on why we develop robots and AI and for whom. This is not just to be more ethical, but also because a surprising number of the robots in REELER are to some extent founded on public funding (nine of eleven cases), and thus seem to a have a direct public responsibility. However, REELER research has also shown that collaboration in heterogeneous groups, and the alignment of different motives, can be a very difficult process. Even the identification of who to collaborate with (end-users, directly or distantly affected stakeholders) does not seem to be something that can be left to the robot makers to decide. Thus, we have developed a two-pronged strategy meant to steer the technological progress narrative toward a new, richer and more inclusive chapter on robotics.

13.4 The two-pronged strategy

The wider effects of robots explored in part three cannot be solved by robot makers or affected stakeholders alone. Across cases, from educational consumer robots to commercial service robots or industrial robots, we have found that the developed robots simultaneously in- and excludes people, put new demands on users and directly affected stakeholders, and change environments, habits and work routines. In economic terms, REELER has shown that collaborations, rather than linear models of innovation, lie at the heart of developmental processes. We have also shown that affected stakeholders are rarely included in these collaborations. Even if robot developers exercise relational expertise and engage in collaboration with affected stakeholders, a built-in asymmetry remains as these collaborations are likely to be initiated by the robot makers with focus on the robot developers' chief activity: robot development.

The original goal of the REELER project was to align robot makers' visions of a future with robots with empirically-based knowledge of human needs and societal concerns, through a new proximity-based human-machine ethics. We expected that by giving voice to those affected by robots, the project could propose ways to close the gap between robot makers and these affected stakeholders. To that end, we have developed the Human Proximity Model, written research publications, and produced a collection of tools for collaborative learning, including the board game BuildBot, the interactive serious puzzle game Brickster, and other tools for robot developers available in the online interactive toolbox. These tools constitute one pillar in our two-pronged strategy.

Though these tools are likely to raise awareness, they may not be able to proactively change existing circles of collaboration. Thus, if the sometimes diverging motives of affected stakeholders (sometimes, but not always, conflating with societal needs) and robot makers are to be aligned, we also need experts with a core expertise in aligning different motives across groups with different cultures, values, understandings, and (gendered, national, and economic) backgrounds.

Collaborative learning remains a key term, and as explored throughout this publication, the robot makers have many good motives for collaborating with each other. What we call for is collaboration between not only end-users and robot developers, but also collaborations with end-users and directly affected stakeholders, which the ethnographic research point to as potentially advantageous for robot developers. Yet, collaboration with end-users and directly affected stakeholders has also proven to be a minefield of time and money challenges for robot developers.

This is why we suggest a novel education/profession, *alignment experts*, who will take on the role as 'go-betweens' aligning the public and political expectations of a robotic future with the robots being developed. Since alignment experts are to fill the gap between the existing collaborations in the inner circle (with their spokespersons), and affected stakeholders, they would need insights into both technological developmental processes and affected stakeholders' life worlds.

These experts will have the basic task of aligning the motives of the robot makers (including engineers, politicians, robot buyers, and funding agencies) with the real-life needs of end-users, and directly and distantly affected stakeholders. Alignment experts should be able to enhance relational expertise by ensuring more proximity between robot-makers and affected stakeholders, making all parties involved more aware of their own relational responsibility. This definition places the responsibility for learning about each other on both robot developers/makers and affected stakeholders/end-users, with the alignment experts acting as intermediaries ensuring human proximity and alignment of robot functions and applications with human needs and societal concerns.

One the one hand, our research recommend that alignment experts are independent of the inner circle as they must be free of various interests in funding schemes and regulations (contrary to the application experts studied in REELER). On the other hand, the strong culture of engineering within the inner circle of robotics suggests that for alignment experts to be successful, their competences and work methods must be accepted by the (powerful) people engaged in robotic business. This point is partly tied to the ways robot developers typically get and develop their ideas. The catalyzing ideas that initiate projects often come from environments familiar to the robot developers; from technological developments in the field of robotics, or from answer to demands from customers/companies, policymakers, and funding agencies. That is, the design and development of a product is likely to primarily be initiated by the company deciding to develop it. Alignment experts are, however, expected to be able to point to societal needs, to which the robot developers present a technical solution Alignment experts can then be useful in exploring whether the technical solution matches the needs of the affected stakeholders. In that respect, the REELER research also points to a potential for new robot ideas increasingly coming from end-users or other affected stakeholders through alignment experts.

In addition to translating (societal) needs into potential robot ideas, alignment experts should also feed into the debates on ethics to ensure that the political and academic discussions are relevant to and take affected stakeholders' perspectives into account. The profession would entail in-depth studies of what matters to those affected by robots, how to avoid pitfalls stemming from normative thinking, and which types of situated knowledge could be the basis of the new educations needed in a robotic society.

Our main conclusion is therefore:

In order to ensure ethical and responsible robot design, it is essential to work on a two-pronged strategy which entails:

a) *enhancing robot developer's awareness of the group of affected stakeholders*

b) *aligning robot makers' and affected stakeholders' motives by increasing human proximity through the involvement of alignment experts, for effective collaborative learning.*

This will ensure a reality check on both robot markers perceptions of stakeholders everyday lives and stakeholders perceptions robots – and thus a reality check on our shared future.

Thus, we do not see a future where enhanced ethical awareness is the sole responsibility of robot developers – but a future of relational responsibility that involve all stakeholders helped by, among others, alignment experts. In this way we can begin a new chapter in the great narrative of how technology, like robot and AI, can shape a brighter future for us all.

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Perspectives on Robots brings forth voices of different stakeholders engaged in or affected by new robot development to deliver a reality check on what robots are and what we can expect them to do.

How will the robots developed today influence the nurses, teachers, physiotherapists, car mechanics, and cleaning staff of the future? And how are these potential users currently involved in the processes of robot development?

This research-based publication addresses these questions and more. Written together by an interdisciplinary team from the fields of anthropology, economics, engineering, sociology, and philosophy, the book raises awareness about ethical issues in robot development. Herein, you will find discussions on:

- a robot ethics that considers users holistically in their everyday lives,
- the practices needed to spark new types of collaboration and alignment in design,
- the fears, expectations, and consequences of robotization, and
- the strategies essential to ensuring that innovation is for the shared benefit of robot makers and affected stakeholders.

REELER

REELER (Responsible and Ethical Learning with Robotics) is a project based on ethnographic and economic studies of robot development made in collaboration with engineers. On our website we provide more information about the project, supplementary publications and chapters, descriptions of our methods, novel research approaches such as sociodrama and minipublics, and an awareness-raising toolbox for engineers who want to learn some of the pitfalls of not taking the perspectives of affected stakeholders into account - plus BUILDBOT, a downloadable fun game to enhance ethical awareness.

www.responsiblerobotics.eu

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