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# **PEERS: PERSUASIVE EDUCATIONAL AND ENTERTAINMENT ROBOTICS**

A DESIGN-BASED RESEARCH APPROACH TO  
SOCIAL ROBOTS IN TEACHING AND LEARNING

**BY**  
**LYKKE BROGAARD BERTEL**

DISSERTATION SUBMITTED 2016



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## CV

Lykke Brogaard Bertel received her Master in Information Architecture and Persuasive Design from Aalborg University in 2011, specializing in persuasive human-robot interaction. She continued this work as a consultant at the Danish Technological Institute, Center for Robot Technology and started as an industrial PhD student at the Department of Communication and Psychology at Aalborg University in 2012. Lykke Bertel is affiliated with the Center for Health and Human-Interaction Technologies at DTI and the AAU eLearning Lab (eLL) – Center for User Driven Innovation, Learning and Design as well as the Aalborg U Robotics group. Her research interests are in the fields of human-robot relationships, educational psychology and participatory design. In her PhD thesis, Lykke Bertel studied design-aspects of robot-supported learning in primary schools and special education.





# ENGLISH SUMMARY

In this thesis I investigate the potential of social robots in education and develop the concept of Persuasive Educational and Entertainment Robotics (PEERs). The concept of PEERs is informed by theories, design principles and related research in Persuasive Design, Human-Robot Interaction and learning design.

The applicability of the concept to real-world learning environments is explored through three independent case studies in diverse and complex educational settings: autism education, formal and informal learning in a health education setting and cross-disciplinary projects related to Science, Technology, Engineering and Math (STEM) in primary and secondary education. In the case studies, I used existing robotic platforms; the zoomorphic PARO seal and the humanoid robot NAO.

The research method is inspired by Design-based Research, focusing on defining and refining methods and guidelines for involving teachers and practitioners in the development of robot-supported designs for learning and on applying and evaluating these designs in practice, in natural settings and in collaboration with users.

The dissertation is paper-based and contains two separate parts: a collection of five published research papers covering different aspects of my work (a separate publication) and a ‘wrapping’ comprising five chapters that link the papers to overall theoretical, methodological, empirical and ethical aspects of the thesis.

The project’s main contributions are revised persuasive principles for the design and application of social robots in education as well as methodological guidelines for involving users and practitioners in the design of robot-supported persuasive interventions. Furthermore, the project documents concrete and practical experiences with the two robots as mediating objects in educational settings. Through theoretical and empirical inquiry a particular theme has emerged: the *symmetry of the interaction* between a child, teacher and a social robot and a surprising persuasive potential in the robot’s *‘inferiority’ to the child* (because of technical flaws and inherent insufficiency, or because it is contextually articulated as such). Thus, this thesis particularly focuses on the notion of being a *‘peer’* as a possible key to motivation and persuasion in human-robot relationships for learning.

*This industrial PhD project is a collaboration between the Danish Technological Institute, Center for Robot Technology and Center for Health and Human Interaction Technologies and Aalborg University, Department of Communication and Psychology. The project is partly funded by the Danish Agency for Science, Technology and Innovation.*



# DANSK RESUME

I denne afhandling undersøger jeg sociale robotters persuasive potentiale i undervisningssammenhænge og udvikler begrebet Persuasive Educational and Entertainment Robotics (PEERs). Dette begreb er informeret af teorier, design principper og relateret forskning i persuasivt design, menneske-robot interaktion og læringsdesign.

Begrebets anvendelighed i konkrete undervisningsmiljøer er undersøgt gennem tre uafhængige casestudier i forskelligartede og komplekse læringskontekster: hhv. specialundervisning med fokus på autisme, formel og uformel læring i sundhedsfremmende uddannelsesinitiativer samt tværfaglige projekter relateret til Science, Technology, Engineering and Math (STEM) undervisning i grundskole og på ungdomsuddannelserne. I casestudierne benyttede jeg eksisterende robotplatforme: robotsælen PARO og den menneskelignende robot NAO.

Min forskning er design-baseret og har haft særligt fokus på at udarbejde og tilpasse metodiske retningslinjer for inddragelse af lærere og praktikere i udviklingen af robot-støttede læringsforløb, samt for anvendelse og evaluering af disse i praksis, i deres naturlige omgivelser og i samarbejde med brugerne.

Afhandlingen er artikelbaseret og indeholder to separate dele: en artikelsamling med fem publicerede forskningsartikler, der dækker forskellige aspekter af mit arbejde (separat publikation) samt en ”kappe” bestående af fem kapitler, der knytter disse artikler til teoretiske, metodiske, empiriske og etiske overvejelser. Afhandlingens vigtigste bidrag er en række reviderede persuasive principper for design og anvendelse af sociale robotter i undervisningssammenhænge samt metodiske retningslinjer for inddragelse af brugere og praktikere i udformningen af persuasive, robot-støttede interventioner. Derudover dokumenterer projektet konkrete erfaringer vedrørende de to robotters potentiale som medierende objekt i læringskontekster. Særligt et tema fremhæves gennem teoretiske og empiriske refleksioner: *symmetrien i samspillet* mellem barn, lærer og sociale robotter samt det overraskende persuasive potentiale i robotens mulige ’underlegenhed’ i forhold til barnet (som konsekvens enten af tekniske fejl, iboende mangler eller fordi den er kontekstuel artikuleret som sådan). Således fokuserer denne afhandling særligt på begrebet ’peer’ (”ligemand”) som en mulig nøgle til motivation og persuasion i menneske-robot relationer i læringssammenhænge.

*Dette erhvervsPhD-projekt er et samarbejde mellem Teknologisk Institut, Center for Robotteknologi og Center for Velfærds- og Interaktionsteknologi og Aalborg Universitet, Institut for Kommunikation og Psykologi. Projektet er støttet af Styrelsen for Forskning og Innovation.*



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# PREFACE

In this thesis I explore the application and potential of social robots as mediating objects in education. The present dissertation is an attempt to conclude three years of theoretical and empirical inquiry, through which I have developed and refined my theoretical concept of ‘Persuasive Educational and Entertainment Robotics (PEERs)’. In this work I have been studying a specific form of social interaction and persuasive intervention: a *persuader* (teacher) brings a robot to a *persuadee* (student) with the purpose to *improve some capability* (curricular or social) *by way of interacting* with the robot. My focus in this particular setting has been twofold:

- 1) to conceptualize and explore empirically the ways in which social robots can mediate interaction, facilitate motivation and support learning in contexts of inherent asymmetry (such as education); and
- 2) to define and refine methodological guidelines for the development, application and evaluation of contextually dependent and socially situated robot-supported learning designs in collaboration with practitioners.

The thesis contains five published research papers, representing different aspects of this particular PEER-concept. This dissertation serves as an introduction, a summary of findings and a presentation of meta-reflections regarding the research process and its contribution to my journey as a developing researcher. It documents decisions, both theoretical and methodological in nature, as well as their practical implications for the design of case studies in rich, intense and complex contexts. It reflects an inquiry-based learning cycle (Bybee et al., 2006; Kolb, 2014; Kolb, Boyatzis, Mainemelis, & others, 2001), through which I have continuously engaged with practice, explored questions related to the application of social robots in educational settings and tried to explain and elaborate on my findings and the concepts I have developed. Thus, rather than a final evaluation, this dissertation is an attempt to gather the threads of three years of ongoing work and form the foundation for new iterations, new inquiry - inspiration and aspiration - to continue the journey and work within the field of social robotics and PEERs.

## BECOMING PEERS

The notion of Persuasive Educational and Entertainment Robotics (PEERs) as a theoretical concept was underway quite a few years prior to this thesis. My research interest in HRI was initially sparked by the introduction of the Japanese robotic PARO seal in Danish nursing homes back in 2007 and a BA project about the many ethical issues and dilemmas that followed. Through interviews with key figures in the public debate, the project presented and discussed ethical arguments in favor of or against the introduction of PARO seals in Denmark.

I was intrigued by the feelings of sympathy, protectiveness and care that a digitalized stuffed animal seemed to intuitively elicit in both elderly people, care professionals, journalists, and myself. At that time, PARO was still only on trial in a few nursing homes and experiences were very limited, thus we did not have much empirical data and the analysis was mainly rhetorical. Today, less than a decade later, more than 210 PAROs are implemented in Danish nursing homes in 70% of the municipalities in Denmark (Klein, Gaedt, & Cook, 2013), and the ethical dilemmas in relation to the use of social robots as assistive and therapeutic technologies not as prominent in the public debate. However, recent feedback from the PARO-community reports that many PAROs are “asleep” in managers’ offices, used only occasionally or with very few residents (Søndergaard, 2013). This surprised me, since initial experiences seemed so promising. I wondered whether it was the robot or rather a consequence of contextual factors affecting its introduction into life and practice of nursing homes.

My interest in social robots and possible applications continued to grow and was combined with insights I had gained from working with technology-mediated interventions and motivation in the EU-project HANDS<sup>1</sup> on persuasive design of mobile ICT platforms in autism therapy and education. Here, I particularly investigated the use of (digital and analogue) reward, and how its persuasiveness seemed to be mediated by the relationship between the child and the teacher and experiences of self-determination (Bertel, 2010; Schärfe & Bertel, 2010). This inspired me to explore the possibilities and ethical issues arising from applying social robots as assistive tools in the inclusion of children with Attention Deficit Hyperactivity Disorder (ADHD) in schools in my master’s thesis (Bertel, 2011). In collaboration with the Danish Technological Institute (DTI), I brought one early generation NAO and the robot Keepon to a local 5<sup>th</sup> grade school class with a variety of skills and needs (including ADHD, dyslexia and bilingualism). After a preliminary introduction of the robot from DTI and a hands-on meet & greet with NAO, the children collaborated in groups to construct robot applications by combining pictures of different social robots with attributions including ‘*roles*’ (teacher, police officer, friend etc.) and ‘*actions*’ (read, listen, scold etc.), which were discussed in plenary. From this workshop and the analysis of the children’s interaction with NAO and Keepon, I saw persuasive potential in the robots’ ability to be both entertaining and educational at the same time, and the concept of PEERs already began to take shape at this early stage. The acronym’s resemblance to the word ‘peers’ is not coincidental, since the children in the workshop seemed to prefer robots in peer relationships as opposed to authoritarian ones, and because it metaphorically embodies my initial hypothesis; that experiences of self-determination and equality in the interaction facilitate motivation. The question of self-determination in contexts of asymmetry thus continued to be one of my research interests, forming the backdrop of this thesis.

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<sup>1</sup> Helping Autism-Diagnosed Navigate and Develop Socially (HANDS). [www.hands-project.eu](http://www.hands-project.eu)

What surprised me in this pilot study was the children's ability to continuously experiment, reflect and adjust their expectations towards the robot and translate this into both technical and ethical considerations. For instance, when realizing that the robot is not (yet) able to 'perceive' information naturally, 'trust' is not (yet) an issue. Telling it a secret is harmless, not because the robot leads the children to believe it is trustworthy, but because it is not technologically advanced or intelligent enough to pass on the information. In this sense, the robot, much like a pet dog, becomes a virtual other, an intersubjective mirror for self-reflection and self-conversation similar to what Weizenbaum argued was the case with the disputed computer program ELIZA (Weizenbaum, 1966, 1976).

I do recognize the importance of a continuous ethical debate on robots in society, particularly regarding interactions with children, as the technology continues to advance and artificial intelligence becomes increasingly attainable. However, these preliminary observations suggested that present ethical issues in the introduction of social robots in education lies less with the child's inclination to let herself be 'deceived' by robots (e.g. as suggested by Sherry Turkle (Turkle, 2007, 2011)) but in designers' and researchers' propensity to conceal the technology's current immaturity and inadequacies in designated Child-Robot Interaction studies. Hence, in this project I wanted to explore the possible applications of social robots "as is", i.e. in their current state, and I found the natural limitations of the robots to be a potential advantage in educational contexts, by facilitating e.g. relational symmetry, professional development and experiential learning.

## TEMPLE GRANDIN – THE MIND THAT BLEW MY MIND

---

*"It takes a ton of professor space in the brain to have all the social circuits" (Temple Grandin, 2010)*

---

What I have found through my case studies on robot-mediated teaching and learning is, that constructive, creative, innovative and positive things can happen when children encounter robots in their 'frailty' (because they act unexpectedly, make mistakes, fall etc. or because their morphology triggers feelings of sympathy and an "urge to care") and that it is just as much the robots' inadequacies as it is their abilities - its complementation of children's spectrum of abilities - that represents the potential of robots in education.

This insight was in part triggered and shaped by an encounter sometime half-way through the project with Dr. Temple Grandin, a designer of livestock handling facilities and a professor of Animal Science at Colorado State University. She has received more than 70 awards for her contributions to animal science and animal

welfare and awarded honorary doctorate at more than 10 different universities. She also has an autism diagnosis. In her 2010 TED talk, “*The world needs all kinds of minds*” (Grandin, 2010) she argues that her mind works differently from others’: she thinks in pictures. Not in the way we are all more or less capable of prompting an inner ‘movie’ based on memory and imagination, but literally as detailed, high resolution images of every single past experience flashing before her eyes. It allows her to access vast amounts of information and it helps her understand the way livestock perceives and reacts to its environment, but it can also be extremely overwhelming and cause anxiety attacks.

This particular attention (some would perhaps say fixation) on detail is considered a common denominator for many people with autism spectrum disorder, which can be both beneficial in some (e.g. intellectually engaging) situations and a limitation in other (socially challenging) situations. According to Grandin, the mind can be more of a cognitive/thinking mind or more social, and the autistic mind tends to be the former; - a specialist mind, either visually, mathematically or verbally, arguing that: “*If you were to get rid of all the autism genetics, there would be no more Silicon Valley*” (Grandin, 2010). It is a tradeoff, a spectrum (of abilities and disabilities), and who are we to say, Grandin asks, that the “social circuits” in the brain are more “true”, more “fulfilling” to the individual and more “valuable” to society than other ways of thinking, other ways of viewing the world?

This realization was a game-changer for me. Having worked with assistive technology and autism spectrum disorder, I very well knew the definitions of and generalizations about ASD:

“...responding inappropriately in conversations, misreading nonverbal interactions, or having difficulty building friendships appropriate to their age (...) overly dependent on routines, highly sensitive to changes in their environment, or intensely focused on inappropriate items” (American Psychiatric Association, 2013).

From an assistive technology point of view, the purpose is to ease and ideally eliminate these ‘symptoms’, since a fulfilling life deprived of the all-pervading social interaction we ourselves indulge in, is simply incomprehensible to the neuro-typical mind. By accepting the generalized notion of the spectrum as a ‘social cognitive and communication *disorder*’ associated with *inappropriate* behavior, I had adopted the underlying view and perception of what constitutes ‘normal’, ‘appropriate’ behavior; not seeing the very fine-tuned range of abilities and disabilities, that the spectrum actually represents and that, upon extension, of course, includes all people (Dudley-Marling, 2004; McDermott, 1993). This is not to say that supporting children with autism in the development of social skills is wrong, which Grandin also emphasizes in her talk. It is important, however, to distinguish between these *skills* as just that, as means to pursue dreams and goals, or as the goal itself.



It is not uncommon to see social robots as a way to “normalize” (socially deviant) behavior, particularly in children with autism; an asymmetrical interaction, in which the human is the one considered ‘flawed’. In contrast to this, I have explored state-of-the-art social robots (with flaws and all) as pedagogic tools for teachers to uncover and unfold children’s (with and without ASD) individual needs and gifts - their spectrum of abilities, and I have done this in partnership with experts, teachers and pedagogic professionals, who are trained and experienced in seeing and supporting children’s interests and potential for development - and to whom, by the way, this idea about children’s spectrum of abilities is not at all new.

## THESIS OVERVIEW

In this thesis, the concept of PEERs is informed by theories, design principles and related work in Persuasive Design, Human-Robot Interaction (HRI) and learning and explored empirically in case-based iterations. Although each case represents its own individual study design, research questions and customized methods for collecting and interpreting data, looking across the case studies a particular theme keeps recurring: namely the symmetry in the interaction between child, teacher and robot and particularly the potential of the robot as a mediating object when it is seen as somewhat inferior to the child, either because of technical flaws and inherent insufficiency, or because it is framed as such within the social context at hand. The idea of robots as vulnerable or in need of assistance might somewhat contradict the overall logics of introducing robots into society in the first place, that is, to *support* and *assist* vulnerable *people*, e.g. elderly, disabled and children. However, when it comes to creating relationships and facilitating motivation and engagement in learning, this instruction- and service providing strategy might not be the only or best approach for robots. Thus, the focus of this thesis is on the concept of being a ‘*peer*’ as a possible key to motivation and persuasion in human-robot relationships.

## FINDINGS

With ‘peer’ learning, the immediate thought might be children of *equal* ability collaborating to achieve some common goal. However, from educational research and practice we know that learning from a ‘more knowledgeable’ other (Vygotsky, 1978) makes sense in many situations, and *being* the more knowledgeable one (i.e. “learning by teaching” (Grzega & Schöner, 2008; Martin, 1985)) is meaningful in other situations. Thus, from this perspective, being *peers* is not about being equal in every way, but about supplementing each other in different, important aspects while ‘learning by doing’ (Dewey, 1910).

In Social Robotics and HRI, the ‘peer’ perspective has gained increasing attention in recent years, not just to increase and sustain technology performance (by ‘keeping the human in the loop’) but also as a possible way to create and maintain human-

robot relationships, e.g. in eldercare (Klein et al., 2013; Lammer, Huber, Weiss, & Vincze, 2014). Child-Robot Interaction (cHRI) researchers have also compared robots as tutors and peers and found that the peer condition holds potential to increase attention, engagement and performance (Ghosh & Tanaka, 2011; Kanda, Hirano, Eaton, & Ishiguro, 2004; Matsuzoe & Tanaka, 2012; Tanaka & Kimura, 2010; Tanaka & Matsuzoe, 2012b; Zaga, Lohse, Truong, & Evers, 2015). However, in most cases the robot's need of assistance or care is "staged", orchestrated as a social role rather than a technological reality. The current insufficiency of the technology itself (in terms of mobility, sensory system and cognition etc.) is not seen as a potential facilitator of motivation. In robotics education, on the other hand, it is much more evident, since the very construction of the robot, e.g. LEGO Mindstorms, is part of the learning design itself, and the construction of the technology inevitably creates awareness of its limitations. In HRI research the unfulfilled expectations of humanoid robots is mainly considered a potential source of error and something to avoid, e.g. by applying Wizard of OZ methods (Green, Huttenrauch, & Eklundh, 2004).

Although Wizard of OZ is a feasible method for rapid prototyping and proof-of-concept evaluation (Dautenhahn, 2007a), I argue 'waiving of the Wizard' in my research (Bertel, Rasmussen, & Christiansen, 2013) since I have found that not only are children able to critically adjust their expectations as they encounter issues and limitations; these very limitations, the flaws and subsequent frustrations might in fact lead to engagement in learning. Just as peer learning is not necessarily about being 'equal' in every way, PEERs is not about concealing the current (in)abilities in social robots, but about recognizing and exploring those as possible contributors to teaching and learning; about complementation rather than compensation.

I see glimpses of the intrinsic motivation and learning in the children's articulation and narration, dynamic categorization and embodied interaction with social robots – all these nuances I hope my PEERs framework will enable both designers, teachers and other professionals using social robots to see. My inquiry into the field of persuasive social robots for learning have been qualitative, case-based and iterative, inspired by Design-Based Research. The main contributions and findings are:

*Theoretically derived and empirically refined persuasive principles for the design and application of social robots in education*

1. Children seem to categorize robots as social actors, however interaction does not have to remain 'fluent' for motivation and learning to occur
2. Children adjust their expectations towards social robots in response to observations, experimentation and reflections in and on action

3. Social robots in ‘frail’ positions elicit intuitive caring behavior in children (anywhere on the spectrum of ability and disability)
4. The taxonomy of Socially Assistive Robotics adds context and complexity to the persuasive principles of social actors, whereas persuasive design adds ethical considerations as it emphasizes the implied intention (and intervention) of any ‘assistive’ technology
5. Constructivist/constructionist approaches to learning address the social context of learning designs as inherently asymmetrical, and the role of the robot as a subsequent enactment of the role of the child, as consumer or co-producer of technological practice

*Methodological guidelines for involving users and practitioners in the design, application and evaluation of robot-supported interventions*

6. Design-Based Research approaches provide the opportunity to continuously adapt and individualize robot-supported learning designs to the context and the user
7. Design-Based Research approaches may provide insights into contextual factors affecting implementation (i.e. knowledge, social relations, values and flow)
8. Users and practitioners are valuable partners in both exploration, co-ideation, co-creation and evaluation phases of HRI
9. An initial *exploratory* phase provides insights into the user’s intrinsic motivation and thus can guide the further design- and development process

From an industrial research point of view I find that my analyses reveal largely overlooked conditions for robot-mediated learning, which may expand present opportunities and possible business cases for both robot developers and educators. Robots in education will inevitably mediate the relationship between students and teachers as well as the rules and roles in this specific context. Whereas this may challenge the original structures of education both practically and socially, it may also provide exciting opportunities for progression. Designers’ and decision-makers’ underestimation of the importance of both ‘integrators’ (e.g. teachers and practitioners’) and end-users (e.g. student’s) subjective motivation for interaction and participation could explain why many PARO’s are “asleep” in Danish nursing homes, and why early NAO-adopters in Denmark report that it is not used as much as they had hoped or would like it to be. Thus, in my opinion introducing social robots as sheer technical training both fails to recognize the inherent context of asymmetry as a condition for robot-supported education and neglects to realize the full potential of the robots as facilitators of learning as well as teaching innovation.

## FORMAT

As mentioned, the dissertation consists of two separate parts: a collection of five published research papers selected as the most significant representations of my work (a separate publication) and a ‘wrapping’ comprising five chapters that link the papers to overall theoretical, methodological, empirical and practical aspects of the thesis. Whereas paper I is mainly theoretical and paper II presents mostly methodological reflections in relation to PEERs, paper III, IV and V present data, analyses and findings from the case studies. A summary of findings and reflections regarding the contributions of each paper to the development of PEERs is included in chapter 4, however I will also attempt to make clear specific contributions of the papers to particular perspectives throughout the five chapters.

- I. Bertel, L. B. (2013). Persuasive Educational and Entertainment Robotics (PEERs). *1st AAU Workshop on Human-Centered Robotics*. Aalborg University Press.
- II. Bertel, L. B., Rasmussen, D. M., & Christiansen, E. (2013). Robots for Real: Developing a Participatory Design Framework for Implementing Educational Robots in Real-World Learning Environments. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013* (pp. 437–444). Springer Berlin Heidelberg.
- III. Bertel, L. B., & Rasmussen, D. M. (2013a). On Being a Peer: What Persuasive Technology for Teaching Can Gain from Social Robotics in Education. Special Issue on Persuasive Technologies for Teaching and Learning. *International Journal of Conceptual Structures and Smart Applications*, 1(2), 58–68.
- IV. Bertel, L. B., & Majgaard, G. (2014). Persuasive Educational & Entertainment Robotics (PEERs) - Aligning Asymmetric Interactions in Education. *HRI 2014 Workshop on Humans and Robots in Asymmetric Interactions*.
- V. Bertel, L. B., & Hannibal, G. (2016). The NAO robot as a Persuasive Educational and Entertainment Robot (PEER) – a case study on children’s articulation, categorization and interaction with a social robot for learning. *Journal of Learning and Media (LOM)*, 8(14).

In the following Chapter 1, I introduce the background of the concept of Persuasive Educational and Entertainment Robotics and Chapter 2 elaborates and positions

PEERs in relation to the research fields of Persuasive Design, Human-Robot Interaction and Learning and their respective cross-fields; Persuasive Learning Designs, Persuasive (Socially Assistive) Robotics and Educational Robotics. I will elaborate on the concept's theoretical and methodological underpinnings, particularly the approach to motivation, social interaction and learning that it represents.

In Chapter 3 I will describe the cases in more detail including the context of the studies, the robotic platforms applied and the planning, processes and products of the projects as well as ethical considerations. In Chapter 4 I provide an overview of the five research papers and summarize findings and in Chapter 5, I take a meta-level perspective and discuss my findings in relation to the future of social robotics in education. The dissertation concludes with reflections on the applicability of my work to real-world learning environments and the contribution of Design-Based Research to the work of designers and developers, suggestions for future work as well as a general discussion about the possibilities and challenges of conducting industrial research.



# CHAPTER 1. INTRODUCING PEERS

## ROBOTS IN EDUCATION – EDUCATION IN ROBOTICS

In 2025, Denmark will be short of at least 9.000 engineers and 4.000 MSc graduates, according to a recent prognosis from Engineer the Future, an alliance of national tech companies, educational institutions and organizations, including the Danish Society of Engineers (IDA) and the Confederation of Danish Industry (DI) aiming to increase children and young people's interest in science and technology *"throughout the educational path from primary school to university"* (Engineer the Future, 2015).

Advanced technologies, 3D printers, robots and visual programming languages are increasingly explored in both formal and informal learning environments (FabLabs, Makerspaces etc.) not only as the subject of specific courses but as a means to increase engagement, creativity and innovation in education (Johnson, Adams Becker, & Hall, 2015). Internationally, similar initiatives to promote interest in Science, Technology, Engineering, (Arts) and Math – STE(A)M can be found, e.g. in recent EU calls for *"innovative ways to make science education and scientific careers attractive to young people"* (European Commission, 2013 and 2015).

In a recent Horizon Project Regional Report on *Technology Outlook for Scandinavian Schools*<sup>2</sup>, which identifies trends, challenges, and technologies to watch in Scandinavian education, robots are one group of such technologies with 4 to 5 years-to-adoption (Johnson et al., 2015). The report suggests that technologies support emerging trends in education, including a *shift from students as consumers to creators, a rethinking of the roles of teachers* and a *rethinking of how schools work*:

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<sup>2</sup> The consortium behind this report includes the Norwegian Centre for ICT in Education, the Swedish National Agency for Education (Skolverket), the National Agency for IT and Learning in Denmark (Styrelsen for Læring og IT) and the New Media Consortium (NMC); an international non-profit consortium of more than 250 colleges, universities, museums, corporations and organizations.

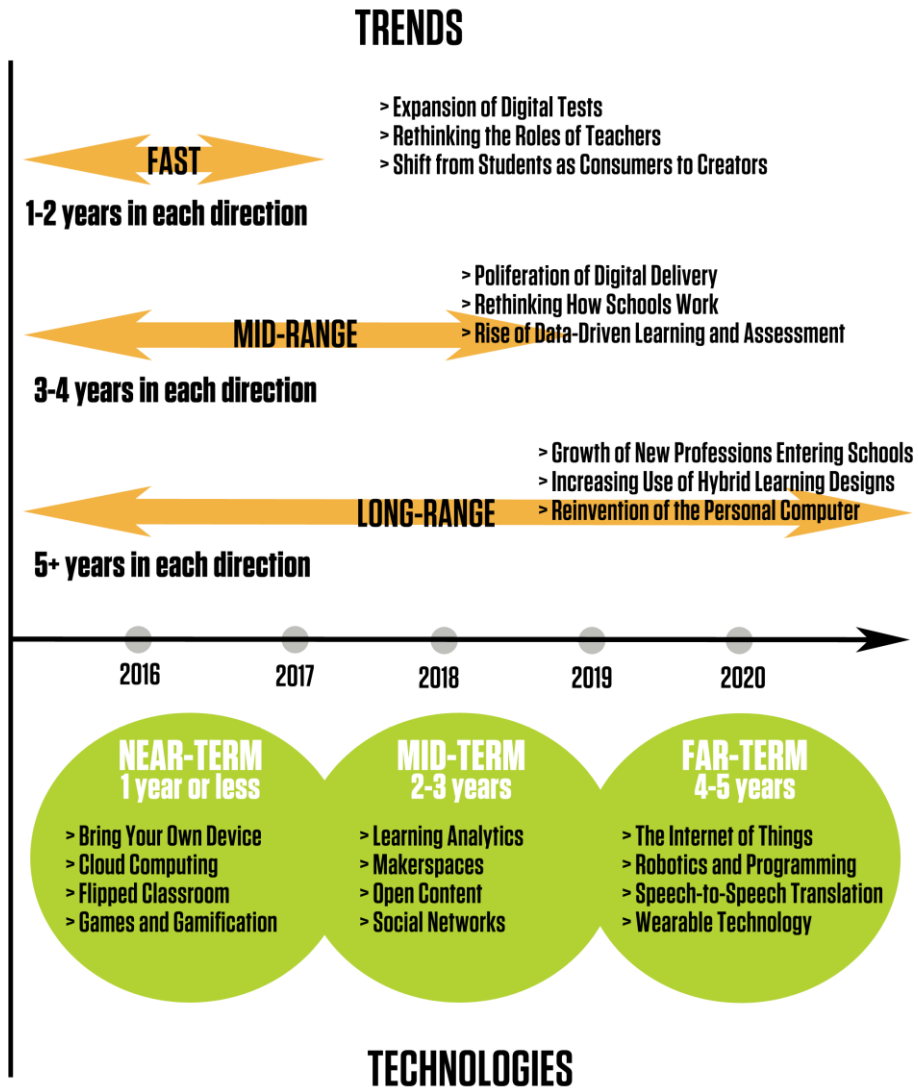


Figure 1: Trends and Technologies in Scandinavian Schools (Johnson et al., 2015)

The report argues that particularly student- and creation-centric cultures of learning in Scandinavian schools allow students to learn how to code at a young age, and this is seen as a key component both in computer science education specifically and as a general stimulation of critical thinking and analysis. However, in relation to robotics, the focus is mainly on students learning *about* robots, and not as much on how



interaction *with* robots might support teaching, learning or creative inquiry, although the report briefly mentions the application of robots in autism therapy and education:

“In some examples, students with spectrum disorders are more comfortable working with robots to develop better social, verbal, and non-verbal skills” (Johnson et al., 2015: 18)

This feeds directly into the increasing demand for inclusion that has emerged in public schools in response to political and economic pressure to reduce costs related to special needs education. Rapid development of assistive technology for children with special needs has followed, and in the field of HRI, autism education in particular was one of the first application of assistive social robots (Feil-Seifer & Mataric, 2009; Scassellati, Admoni, & Mataric, 2012).

As Mataric have pointed out, though, although robots seem to be excellent tools for teaching and learning and a compelling topic for students at all ages, the pedagogy of teaching and learning (about and with) robots is still in its infancy (Mataric, 2004). Thus, thesis emphasizes the development of such a *pedagogy* of teaching robotics and teaching with robots, and in line with the cultural-historical and constructivist approach to human activity and education in particular (Vygotsky, 1978; Lave & Wenger, 1991), the purpose of this project is to understand the mediation and contextual interaction between people (teachers and students) and (robotic) tools in the pursuit of (teaching and learning) goals. Thus, the intention is not to measure the “effectiveness” of certain robots relative to others in the achievement of these goals. Rather, the thesis seeks to explore robots as mediating artifacts and “objects to think (and develop) with” (Papert, 1980); as tools among other tools, to facilitate teaching innovation and create authentic formal and informal learning opportunities.

## **WHY *PERSUASIVE* EDUCATIONAL AND ENTERTAINMENT ROBOTICS?**

The difference between learning *about* robotics and learning *with* robots has previously been addressed. Jeonghye Han distinguishes between educational robotics (i.e. hands-on robotic kits) and r-learning service robots, which generally take anthropomorphized forms (Han, 2010; Han & Kim, 2009). Han argues, that the difference between these two types of robots stems from the primary user groups. Whereas educational robotics is traditionally part of the ‘prosumer’ community, the users of r-learning service robots are mainly considered consumers and a much clearer boundary is drawn between users and developers (Han, 2010).

With Persuasive Educational and Entertainment Robotics (PEERs), which I first coined in paper I (Bertel, 2013), I make a similar distinction between educational robotics and robot-supported designs for learning. As mentioned above, PEERs is a three-dimensional concept informed by Persuasive Design, Human-Robot Interaction

(HRI) and Learning<sup>3</sup> (figure 2). What this adds to Han’s categorization is the understanding that not only do the fields of educational robotics and r-learning service robots have different views on users as either consumers or prosumers, these fields represent entirely different approaches to interaction, motivation and learning, which I will further elaborate in chapter 2.

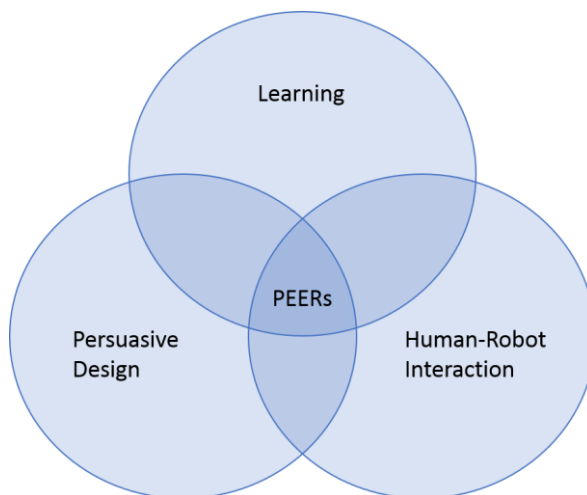


Figure 2: The PEERs model (Bertel, 2013)

As a conceptual framework, PEERs draws from the intersection between HRI and learning theoretically and methodologically. However, the third dimension that Persuasive Design contributes to the concept emphasizes the *intention to change attitudes or behavior* inherent in any teaching and learning design and particularly the part that *context* plays in the realization of this intention. As Han argues, empirical research on r-learning service robots is mostly conducted using an experimental lab-study approach mainly of technological and practical reasons, often leaving out contextual aspects in the analyses. However, as technology advance and become more flexible and robust, it becomes realistic to conduct studies over a longer period of time and in real-world environments, which is generally viewed as necessary in HRI and cHRI (Baxter et al., 2011; Ros et al., 2011; Salter, Werry, & Michaud, 2008).

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<sup>3</sup> In the papers I use the term ‘didactics’ since it is commonly used in Denmark to describe teaching as an act of *design*. Also, ‘learning’ carries some ambiguity within HRI, often referring to ‘machine learning’. However, since ‘didactics’ in English is often used to describe teaching containing a strong moral message, in this dissertation I return to the notion of ‘learning’ and use ‘designs for learning’ as the equivalent to ‘didactics’, hopefully avoiding any misunderstandings with either ‘moralization’ or ‘machine learning’.

## MY DESIGN-BASED RESEARCH ROMANCE

My focus on context in robot-mediated learning emphasizes the importance of the teacher in design and implementation of robot-supported designs for learning. As such, robots as interventions in educational settings address two different levels of persuasion; the students at one level, and the teachers at another. The technology may be the same, but the goals will necessarily differ or perhaps even conflict with each other. My prior research on persuasion, self-determination and mutual goal-setting thus seemed relevant not only in relation to the recipient of persuasive interventions (in this case, students) but also to the designer and facilitator of such interventions (in this case, teachers) (Bertel, 2010; Schärfe & Bertel, 2010).

To address this, the overall methodological approach in the project is inspired by Design-Based Research (DBR), which can be viewed as a particular branch within educational research, emphasizing iterations and user involvement in natural settings (Anderson & Shattuck, 2012; Sanders & Stappers, 2008). Its origin is often ascribed to Barab and Squire (2004), although ideas about contextual situatedness, the examination of particular interventions by continuous iterations of design, enactment, analysis and redesign traces back to Brown, Collins and Cobb (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Collins, 1992) and its methodological heritage even further back, e.g. to Action Research (Lewin, 1946) and collaborative inquiry (Heron, 1996; Reason & Bradbury, 2001).

In educational DBR, the purpose is to test a particular learning environment or tool (i.e. instructional approach, type of assessment, learning activity or technological intervention) together with practitioners, with the aim of improving the design of the intervention as well as to develop theories to better understand the specific teaching and learning issues involved in the intervention (Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003). In contrast to ‘predictive’ research, which describes a (preferably iterative) research process of theory/hypothesis-driven experiments, analyses and reflection, with a focus on theory refinement rather than application of results, the DBR approach emphasizes the partnership and negotiation of research goals between researchers and practitioners:

“The design-based researcher is humble in approaching research by recognizing the complexity of interactions that occur in real-world environments and the contextual limitations of proposed designs. The development of design principles will undergo a series of testing and refinement cycles. Data is collected systematically in order to re-define the problems, possible solutions, and the principles that might best address them” (Amiel & Reeves, 2008).

While the methods in DBR are not new, the intentions and continuous cycle of design-reflection-design (figure 3) seeks to address the complexities inherent in educational technology research in new ways (Amiel & Reeves, 2008):

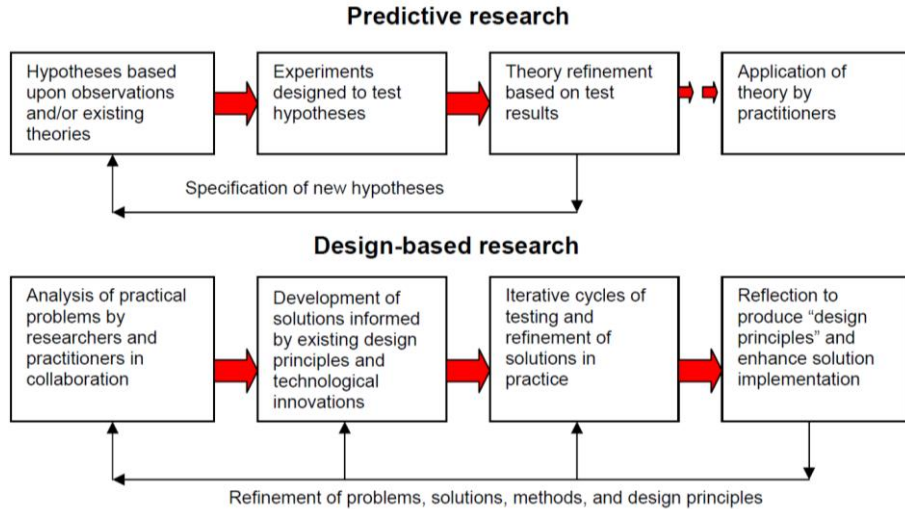


Figure 3: The 'Predictive' vs. 'Design-Based Research' Life Cycle (Amiel & Reeves, 2008)

DBR mostly applies qualitative, descriptive and explanatory methods, using many different data sources including interviews, open questionnaires and observation notes and video (Akker, Gravemeijer, McKenney, & Nieveen, 2006; McKenney & Reeves, 2013; Wang & Hannafin, 2005). This relatively pragmatic approach to data collection is reflected in my own research through the three case studies and their respective methods, data sources and units of analysis, including ethnographic observation, in-situ interviews, focus group interviews, logs, questionnaires and video, which I will describe in more detail in chapter 3.

## TIME, SPACE AND SYMMETRY IN HRI STUDIES

In paper II (Bertel et al., 2013) I discuss *time*, *space* and *structure* as key elements of empirical studies on the basis of what I believed was underrepresented in HRI; user-centered approaches to research and design. However, in retrospection rather than specific methodological *techniques*, time, space and structure (which I have renamed *symmetry*) are scalable *parameters* of any empirical study. Based on feedback from my industrial supervisor Lars Dalgaard and fellow researchers at the second AAU Robotics workshop in 2013, I thus revised the TSS-framework as a generic, visual representation of different methodological approaches to HRI, the TSS-grid (fig. 4).

In HRI, user-centeredness manifests itself mainly by expansions in *time* (duration) and/or *space* (location) of the studies, with ‘long-term’ lab studies (A) and single-encounter studies ‘in the wild’ (B) being at the far end of the time and space axis, respectively (see fig. 4). Whereas HRI and particularly cHRI research is increasingly being conducted both ‘long-term’ and ‘in the wild’ (C), these studies rarely involve participatory or collaborative design- or development processes with users (e.g. teachers or students). This perspective adds a third dimension to time and space; the *symmetry* within the study (i.e. the ‘power balance’ between researchers and users - emphasizing that an empirical research setup, just like a teaching scenario, represents a context of asymmetry between those who *do research* and those who are *being researched*). Adding this third dimension, I believe, illustrates the complexity of ‘user-centeredness’ in user-centered studies. Whereas DBR of course shares similarities with the participatory design tradition, some participatory design methods are applied in the initial exploratory phases for a limited time and in one particular place (e.g. a workshop in a design lab) often prior to the development of the actual technology (D). In contrast, DBR view the subsequent practical implementation as part of the research process and emphasize user-involvement throughout (blue box).

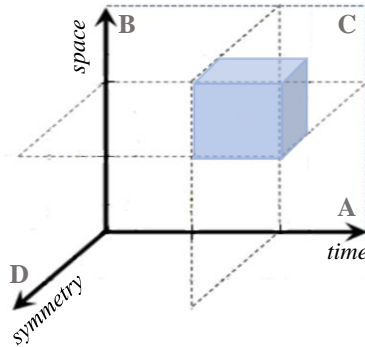


Figure 4: The Time-Space-Symmetry Grid

Whereas my research is positioned within the blue box area, I do not advocate against research approaches in other areas of the TSS-grid. However, I would argue, that the balance between the three dimensions in any research design influences the nature of the research questions one can seek to address empirically. For instance, whereas it would be interesting to see how people’s reactions towards robots in public places generally develops over time, it seems reasonable to argue that the interaction between humans and public space robots (such as intelligent, interactive trash cans (Fischer et al., 2015; Sirkin, Mok, Yang, & Ju, 2016)) would mostly consist of single-case encounters. To simulate natural interaction in such a study, the space-dimension is important (i.e. the natural environment) whereas time and symmetry could be less important, particularly if the purpose is to explore a specific already-defined design

of the robot and the information it instantly and intuitively conveys to users, e.g. about intentions (Yang et al., 2015). However, if the refuse collector emptying the garbage cans is also considered a user in the study, the time and symmetry dimensions could be relevant, since attitudes towards the robots and experiences of usability (e.g. receiving information when it is full, emptying it etc.) may affect the implementation processes and usefulness of the robots in practice.

Child-Robot Interaction (cHRI) research is increasingly conducted in natural settings (Baxter, Wood, & Belpaeme, 2012; Ginevra Castellano et al., 2010; Kory Westlund, 2015; Leite, Castellano, Pereira, Martinho, & Paiva, 2012; Robins, Dautenhahn, & Dickerson, 2009; Robins, Dautenhahn, Te Boekhorst, & Billard, 2004; Setapen & Breazeal, 2012; Short et al., 2014; Wainer, Dautenhahn, Robins, & Amirabdollahian, 2014). However often the studies are conducted in a restricted, pre-defined space within this setting. Also, the 'long-term' aspect of the study is in many cases actually 'serial short-term interaction', meaning that the robot is not a natural part of the teaching environment and interactions with it is not a part of the natural teaching and learning practice but something occasional, dependent on the researchers' presence and support. These restrictions are often necessary to ensure documentation (e.g. positions of cameras) or the performance of the robot (e.g. position of sensors - or a wizard). Whereas this research indeed provides important insights into cHRI, the purpose as such is not specifically to equip teachers with guidelines on how to put these robots or results into practice. This is essentially, what DBR claims to pursue.

In a post-positivist paradigm lens, DBR methodologies are sometimes viewed as "non-scientific" since they do not adhere to the rules of either purely empirical observational or ethnographic research or purely empirical experimental research with fixed and isolated variables, but use "quasi-experimental methods" in which the experimental design is going through changes and modifications throughout the intervention. However, as DBR is inherently exploratory and its purpose primarily to develop theories and hypotheses (Brown, 1992) it should be evaluated as such. Acknowledging that DBR does not necessarily provide results generalizable across contexts, it commits to ensure the applicability of the results to its specific practice.

### **DBR AND TSS: CRITICAL REMARKS**

Although iterations are essential in DBR, a recent systematic review of DBR found that most DBR studies only tested the intervention by one iteration because of resource and time constraints and that explicit specification of the revision of the intervention has decreased in the literature (Zheng, 2015). Also, the effectiveness of designs and interventions is mostly captured by measuring cognitive processes in learners (i.e. learning achievements) and few measure attitudes of learners (Zheng, 2015). In this respect, the review focuses on learners and does not directly address whether DBR research generally report results on teaching practices. The review does, however, emphasize that multiple cross-contextual iterations are required to

refine theory, methods or tools and that caution should be made when generalizing findings drawn from local contexts (The Design-Based Research Collective, 2003). Other critical perspectives on educational DBR includes that of Dede (Dede, 2004) who emphasizes the importance of settings standards that improve the quality of DBR and refining innovations so that they matter to the audience for our research.

My research run into similar challenges with re-iteration because of time constraints (in the PARO case there were two iterations, whereas the iterations on the learning designs in the NAO cases were across the entire group of participants and not with each individual teacher). Although I do recognize that multiple iterations allow for development and that testing with a variety of groups lends greater transferability to the design itself, I would argue that theory development is beyond the individual DBR study's obligation. The researcher represents an experiential learner, and conducting research within a specific field as a career represents in itself an iterative cycle of action, reflection, conceptualization and application (Miettinen, 2000). Thus, while the ultimate goal in DBR is theory development, this might only occur after a lifetime of engagement within a particular field. What the design researcher is committed to, however, is the development of design principles or guidelines, derived and refined empirically, richly described and continuously refined (Amiel & Reeves, 2008), which others interested in studying similar settings and concerns can implement, discuss, refine and further develop.

This also applies to the applicability of the TSS-grid. While illustrating the complexity of contexts and user-centeredness in HRI, from a technological point of view it does not convey information about the complexity or requirements of the robot to perform in particular environments. However, as argued in (Brooks, 1986; Majgaard, 2011), the experienced complexity of a robots behavior is not fixed but mediated by the complexity of the robot system and the environment:

“Complex (and useful) behavior need not necessarily be a product of an extremely complex control system. Rather, complex behavior may simply be the reflection of a complex environment. It may be an observer who ascribes complexity to an organism - not necessarily its designer” (Brooks, 1986:15).

The contribution of DBR and TSS to the development and refinement of PEER-supported learning design principles and guidelines (for designers as well as practitioners) in this thesis is thus its devotion to practice and partnership with practitioners and the general understanding that real change requires re-iterations, on problems as well as their solutions.





## CHAPTER 2. POSITIONING PEERS

In this chapter I will elaborate on the framework of PEERs and its theoretical and methodological underpinnings. Based on a detailed PEERs model (figure 5), which the respective intersections: A. *Persuasive Learning Designs*, B. *Persuasive (Socially Assistive) Robotics* and C. *Educational Robotics*, I will try to make explicit how related research informed the development of the concept and in what ways it differs from and contributes to existing theories within related established research fields.

With regard to my research questions, the PEERs model particularly addresses aspects of the conceptualization of PEER-related theoretical principles and guidelines on motivation and learning, whereas the TSS-grid directs the empirical investigation of PEERs in the particular complex, asymmetrical context that is education.

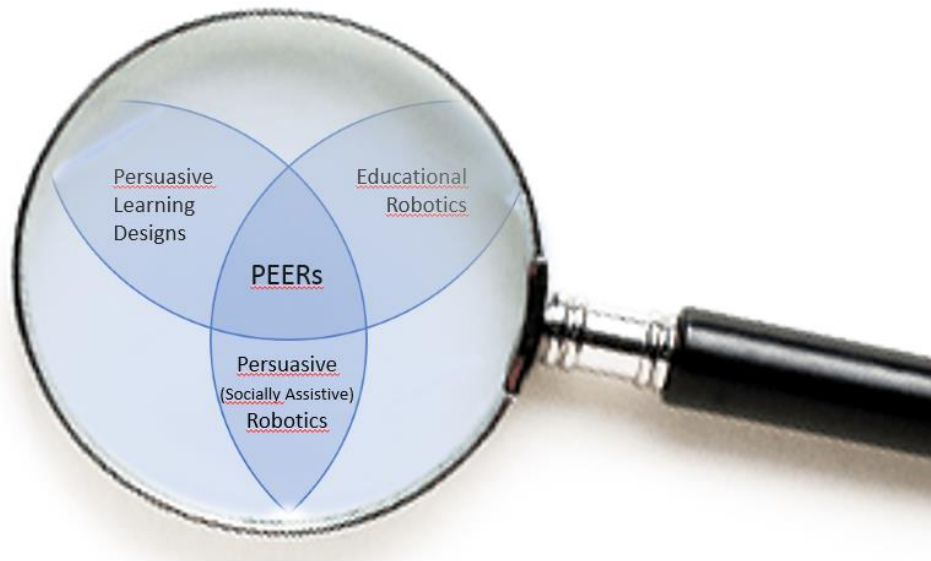


Figure 5: Detailed PEERs model (Bertel, 2013)

## PERSUASIVE DESIGN

Persuasive Technology was originally established as a research field by B. J. Fogg in 2003 with his book “Persuasive Technology: Using Computers to Change What We Think and Do” (B. J. Fogg, 2003). The definition of persuasive technology as “*any interactive computing system designed to change people’s attitudes or behaviors or both without using coercion or deception*” (Fogg, 2003:1) encompasses a wide range of technologies, however sharing common purposes, e.g. to promote a healthier, happier or more sustainable lifestyle to improve the state of health for the user, the society or the environment (Persuasive Technology, 2016).

Although the book is more than a decade old and the field of Persuasive Technology expanding and developing rapidly, I still find Fogg’s original categorization of the roles of the technology in HCI very useful when it comes to understanding the potential roles of robots in HRI; as *tool*, *medium* or *social actor* (B. J. Fogg, 2003):

- *Tool*: simplifying or guiding tasks, tailoring the interaction to the user, providing the possibility of self-monitoring and surveillance, suggesting and rewarding behavior
- *Medium*: providing compelling experiences and the opportunity to explore complex cause/effect relationships through the simulation of environments or objects
- *Social Actor*: interacting with the user socially, providing feedback and social support, gaining trust through similarity or authority and eliciting reciprocity

Most persuasive technologies will incorporate principles from all three categories, but often associates with one category more than the others. For instance, although screen-based technologies that provide information about water consumption may utilize both simulation and social strategies (e.g. providing feedback or simulate the effects of a household’s water consuming behavior on global access to water), they are probably still considered mostly a household tool. Similarly, social robots may in some cases be considered tools or simulation (Fogg refers to baby simulators as ‘simulating objects’, whereas they could also be considered robotic), however in most persuasive technology research, robots are referred to as social actors or agents (Ham, Bokhorst, Cuijpers, van der Pol, & Cabibihan, 2011; Ham & Midden, 2009, 2014; M. Roubroeks, Ham, & Midden, 2011a; M. Siegel, Breazeal, & Norton, 2009; M. S. Siegel, 2008; Vlachos & Schärfe, 2014).

From a user-centered perspective, the principles of persuasive technology are not universal principles that designers can randomly choose from when developing technologies for behavior change. In this perspective, the technology is part of a *persuasive intervention* in which other contextual factors (e.g. the surroundings, timing and initial attitudes or perceptions of the persuadee) may also support or

obstruct behavior change (Lu, Ham, & Midden, 2016; Gram-Hansen, 2016; Stibe & Cugelman, 2016; Lockton, Harrison, & Stanton, 2010; Torning & Oinas-Kukkonen, 2009; Oinas-Kukkonen & Harjumaa, 2008; Davis, 2008; Basten, Ham, Midden, Gamberini, & Spagnolli, 2015). Some of this work draw on traditional rhetoric, particularly the notion of Kairos<sup>4</sup> as a way to ensure that the persuasive intervention is initiated at the appropriate time and place and in the appropriate manner (Gram-Hansen & Ryberg, 2013, 2015; Räisänen, Oinas-Kukkonen, & Pahlila, 2008; Tikka & Oinas-Kukkonen, 2016).

A user-centered approach to HCI and behavior change emphasizes the integration of ethical considerations in technology design processes and proposes a participatory and value-sensitive approach to technology development (Davis, 2009; Gram-Hansen & Gram-Hansen, 2013; Kaptein, Eckles, & Davis, 2011). The ethical discussion is grounded in an understanding of ‘intention’ not as something that either designer or user possesses (i.e. implying that the designer’s intention might be ethical even though the actually use of the same technology might not) but as something continuously negotiated in the interaction between the user and the features and affordances of the technology in complex contexts (Gram-Hansen, 2016).

This approach contributes to the PEERs framework in several aspects. One being the understanding of technologies as mediating artifacts not precluded from embedded social roles, rules and structures within the context; the other being methodological reflections regarding how to address the context of persuasion through user-centered design methods in the development of technological practice. Whereas the point of departure for discussing contextual embeddedness in persuasive designs is mostly physical characteristics of the contexts and the challenge of sustaining behavior change across different localizations, my take on and contribution to context in persuasive design is rather that of a social one; constituted by the relationship between persuader (e.g. teacher) and persuadee (e.g. student), which I will elaborate further in my the section on ‘Persuasive Learning Designs’ in this chapter.

## **HUMAN-ROBOT INTERACTION**

Human-Robot Interaction (HRI) is highly interdisciplinary field with research groups from robotics, computer science, engineering, design, and the behavioral and social sciences and international conferences and journals (e.g. the Symposium on Robot and Human Interactive Communication (RO-MAN) and Human-Robot Interaction (HRI) conference and journal) addressing:

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<sup>4</sup> Kairos (καιρός) is an ancient Greek word meaning the right or opportune moment (the supreme moment), which is different from the chronological or sequential time (Kronos). In traditional rhetoric, Kairos emphasizes context, i.e. the appropriate time, place and manner (Gram-Hansen & Ryberg, 2013).

“...how people interact with robots and robotic technologies, how to improve these interactions and make new kinds of interaction possible, and the effect of such interactions on organizations or society (“Journal of Human-Robot Interaction,” 2016)

The term Socially Interactive Robotics (SIR) defining robots whose sole purpose is to engage in social interactions was defined in 2003 (Fong, Nourbakhsh, & Dautenhahn, 2003), however until recently it was mostly considered a sub-topic and niche within robotics and HRI. Since then, the distinct field of Social Robotics has gained ground internationally and in 2009 established its own annual conference (ICSR) and journal (JICSR) (“Social Robotics,” 2016). Today even more Social Robotics sub-area conferences and workshops have emerged including Child-Robot Interaction (cHRI) such as the New Friends conference on social robots in therapy and education (“New Friends 2015,” 2015) and the International Workshop on Educational Robots (“WONDER 2015,” 2015) which made its first appearance in connection to the ICSR conference in 2015.

Initially, the ‘interaction ability’ of a robot covered both Human-Robot Interaction, Robot-Robot Interaction and interaction safety, and the HRI field as a whole thus includes robots as diverse as industrial, space, surgical and assistive (public, healthcare, welfare and educational) robots<sup>5</sup>. SIR, however, focuses mainly on the last, since social and interactive skills are in many cases considered prerequisites in the interaction between humans and assistive technologies (Castellano et al., 2008; Dautenhahn, 2007b; Dautenhahn et al., 2005). Whereas both HRI and SIR originally focused mainly on technical aspects of the interaction, in recent years they have merged with a more human-centered approach from the social sciences and humanities including techno-philosophy, e.g. (ROBO-PHILOSOPHY, 2016) and most of the developing HRI and SIR platforms are tested in (more or less) realistic environments not just to evaluate and improve algorithms, but also to understand how interacting with robots might affect humans and society in general.

The originally taxonomy of SIR, which I took as my starting point in paper I (Bertel, 2013) and return to discuss in relation to persuasive design in paper III ((Bertel & Rasmussen, 2013a) defines the following characteristics and key components in social HRI (figure 6):

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<sup>5</sup> E.g. according to the H2020 Robotics Multi-Annual Roadmap which is a detailed technical guide identifying expected progress within the European Robotics community. The roadmap is updated annually by expert Topic Groups formed by euRobotics AISBL (a non-profit association with representatives from more than 250 robotics companies, universities and research institutions). Based on this roadmap, SPARC (a public-private partnership between the European Commission and euRobotics AISBL) develops recommendations for the Commission for funding under Horizon 2020. (SPARC Robotics, 2016).

<b>Socially Interactive Robots</b>		
<i>Properties</i>	<i>Description</i>	<i>Example</i>
Morphology	Establishes social expectations of the interaction and provides information about the intended use of the robot	Anthropomorphic Zoomorphic Carricatured Functional
Emotions	Facilitate credibility in HRI and serve as feedback to the user about the robot's internal state	Anger, fear, sadness, joy, surprise, neutral and combinations
Dialogue	Exchange and interpretation of symbols and information about the context of the interaction	Synthetic language Natural language Non-verbal cues
Personality	A set of qualities particularly significant for a specific robot	Tool (reliable), Pet (lovable), Character, Supernatural, Human-like
Perception	Perceptual abilities for engaging in social interaction with humans	Face/gaze tracking Speech/gesture recognition Tone of voice
User modeling	The ability to adapt to and shape the interaction in relation to specific user characteristics	Technological literacy Experience Cognitive abilities
Situated learning	Transferring information, skills and tasks between robots and humans	Imitation Machine learning
Intentionality	For people to be able to assess and predict a robot's behavior, expressions of intention are necessary	Targeted movement and behavior Theory of Mind Joint attention

*Figure 6: The Taxonomy of Socially Interactive Robotics (Fong et al., 2003)*

Within the HRI community there tend to be somewhat of a divide between those who focus mostly on ‘external’ aspects of interaction (e.g. the morphology and personality of the robot, its verbal and non-verbal expressions of emotions and intentions) and those who are concerned with the ‘inner’ abilities of the robot (i.e. the perception/modeling of the interaction partners and the surroundings, processing language and learning). Those interested in the latter direct their empirical research towards proof-of-concept and the user scenario is regarded as an isolated environment, a testbed, for the development and documentation of this improvement (Han, 2010; E. S. Kim, Paul, Shic, & Scassellati, 2012). Empirical research on ‘external’ aspects of the interaction tend to focus on the users and their attitudes towards particular aspects of robot’s appearance and expressions of intentions and emotions (Bartneck, Kanda, Mubin, & Al Mahmud, 2009; Bartneck, Nomura, Kanda, Suzuki, & Kennsuke, 2005; Trovato et al., 2013; Trovato, Kishi, Endo, Hashimoto, & Takanishi, 2012; Vlachos & Schärfe, 2012, 2015). Some research in this area also investigate whether unwritten rules of human-human interaction and communication applies to interaction with robots as well, e.g. *turn-taking* (Breazeal, 2003; Chao & Thomaz, 2010; Kose-Bagci, Dautenhahn, & Nehaniv, 2008; Sidner, Lee, Kidd, Lesh, & Rich, 2005), *proxemics and personal spatial zoning* (Mumm & Mutlu, 2011; Takayama & Pantofaru, 2009; Walters et al., 2005, 2009) and *touch and embodied interaction* (Dougherty & Scharfe, 2011; K. M. Lee, Jung, Kim, & Kim, 2006; Yohanan & MacLean, 2012).

In both technology- and human-centered HRI studies, the dominant methodological approach is lab studies, and one of the preferred methods for evaluating HRI from a user-centered perspective is to have the users themselves assess certain aspects of the interaction on Likert scales. As mentioned earlier the lab study approach is debated in Child-Robot Interaction, though, since cHRI research in general advocates natural interaction scenarios (“Evaluating Child Robot Interaction,” 2016). Furthermore, the Likert scale assessment is problematized, particularly with younger children since they often need support in expressing how they feel about technology and thus tend to turn towards the extremes on a Likert scale, and cHRI researchers have thus been exploring new approaches to evaluation in cHRI, such as forced-choice between descriptors, pie chart and pictorial descriptions (Belpaeme et al., 2012) and alternative approaches to detecting and assessing engagement (G. Castellano et al., 2012; Corrigan et al., 2013; Sidner, Kidd, Lee, & Lesh, 2004; Sidner et al., 2005; Zaga, Truong, Lohse, & Evers, 2014).

From a methodological point of view, the Design-Based Research approach contributes to cHRI with new perspectives and methods for evaluating interaction and engagement, since it emphasizes the collaboration between researchers and practitioners and thus directly includes the evaluation from experts (i.e. teachers), who are trained in assessing interaction and engagement (e.g. in learning) and have personal experience with each individual child’s motivation and interaction patterns.

## LEARNING

In the initial introduction of PEERs in paper I (Bertel, 2013) I reflect on the traditional paradigms of behaviorism, cognitivism and constructivism and discuss how they may contribute to the development of a theoretical framework for PEERs. My own understanding of teaching and learning naturally developed through the thesis and practical experiences in the case studies, and particularly the field of Educational Robotics contributed to my understanding of PEERs and the potential of social robots as mediating artifacts in education, which I will elaborate later in present chapter.

In the paper I argue, that the constructivist approach is particularly relevant, since my focus is socially interactive robots and as such agents in a social realm. I believe, though, that components in all three paradigms contribute to PEERs with different things. Although I agree with the view that the original behavioristic approach to motivation and learning is somewhat mechanical and simplistic, I do think that the modern interpretations of behaviorism generally considers behavior much more complex and dynamic and mediated by many factors apart from the expectancy of pleasure or pain, e.g. informed by theories such as the Elaboration Likelihood Model (Petty & Cacioppo, 1986), Social Cognitive Theory (Bandura, 1977, 1986) and Self-Determination Theory (Ryan & Deci, 2000; Cameron, 2006). The behavioral design approach is relevant in education in that it directs attention towards external factors and the specific ‘design’ of the task or target behavior, which potentially motivate the student to perform a task even though it is not intrinsically motivating. This is relevant in PEERs, since ‘learning’ is in our culture in many cases framed as separate from ‘play’ (associated with intrinsic motivation) and thus in many cases considered non-intrinsically motivating by default.

What *cognitivism* contributes to PEERs is a perspective on the interrelationship between persuasion and learning. While learning is considered an internal process through which knowledge is constructed, this process will also in many cases involve a change in behavior and/or attitude towards something. The cognitivist approach to learning view existing knowledge as organized in mental schemes which are used to interpret new information either by assimilation (unconscious adaptation of the outside world to existing understandings and schemes) or accommodation (rejection and further development of schemes to make sense of the world) (Piaget, 1954). These activities are originally considered mutually dependent and constantly interacting as part of the learning process, but the concepts have also been used to identify different forms of learning. Thus assimilative learning is articulated as the hallmark of traditional teaching, whereas project-based learning has been highlighted as promoting significant accommodative learning (Hermansen, 1996).

From a persuasive design perspective, the act of teaching can be considered a persuasive intervention and the difference in types of learning reflects when an attitude or behavior is *shaped*, *changed* (accommodation) or *reinforced* (assimilation)

(G. Miller, 1984). Similarly, what distinguishes persuasive design from other types of (non-coercive and non-deceptive) behavioral change such as *nudging* is that whereas nudging is about gently and seamlessly “pushing” people in the ‘right direction, i.e. assimilate the target behavior, “true” persuasion (i.e. active and sustained behavior change across contexts) requires a change in attitudes as well, which requires some sort of accommodative learning (Gram-Hansen & Ryberg, 2015). For instance, whereas a water tap sensor might reduce water consumption, the choice to improve water consuming behavior in general requires an attitude change, which again requires some sort of ‘accommodative learning’ (i.e. a new perspective on everyday water consumption and its environmental effects as well as methods for reducing it). Whereas nudging favors the effortless (perhaps even preferably subconscious) behavior change, thus relying solely on the ethical consideration of the designer, persuasive designs for learning will emphasize the learners’ attitude change and conscious commitment to actively change behavior.

Attempts to explain a child’s progression through Piagetian stages typically have emphasized interactions with the physical (rather than the social) world (S. A. Miller & Brownell, 1975). The *constructionist* approach builds on this approach and directs attention towards the characteristics and qualities of the interaction between the child and the physical world (S. A. Papert, 1980). Papert argues, that ‘constructing’ and experimenting with technology in ‘real-world’ problem-solving exercises facilitates the child’s experiences of motivation and meaningfulness (S. A. Papert, 1980). Majgaard considers Papert’s framing of learning as ‘debugging’ equivalent to assimilation, whereas accommodation occurs when the ‘debugging’ involves rephrasing and re-orientation of the program and its context (Majgaard, 2011).

Although the social interaction (e.g. between peers) is not excluded from cognitivism (S. A. Miller & Brownell, 1975; Piaget, 1932) most educational research focusing on social interaction in learning is associated with *constructivism* (Vygotsky, 1978, 1986), emphasizing particularly the interaction between the learner and a more knowledgeable other and the zone of proximal development defined as the distance between current (individual) and potential (collaborative) capacity for problem solving under the guidance of such more knowledgeable others (Chaiklin, 2003). In relation to PEERs, this approach to interaction and learning contributes to my understanding of learning as situated (Lave & Wenger, 1991), the context of persuasive learning designs as one of asymmetry (Bertel & Majgaard, 2014), and the persuasive potential of a PEER in the role as a more (or less) knowledgeable other. In the following section, I will elaborate on the PEERs model and go more into detail with where behavioral, cognitivist, constructivist or constructionist thinking have contributed to PEERs and developed my take on social robots for learning.



## THE PEERS MODEL

As mentioned in the beginning of the chapter, the PEERs model identifies and draws from three related interdisciplinary research fields: A. *Persuasive Learning Designs*, B. *Persuasive (Socially Assistive) Robotics* and C. *Educational Robotics*. In the following I will briefly introduce each and discuss their contributions PEERs.

### A. PERSUASIVE LEARNING DESIGNS

Although the field of Persuasive Learning Design does not particularly focus on robotics, its approach to technology-enhanced learning and reflections on persuasion and learning has inspired my own understanding of the role of a robot in persuasive educational interventions. Persuasive Design contributes to designs for learning with two things; 1) the understanding that ‘teaching’ is in fact ‘designing’ and that good teaching requires attention to contextual factors; appropriate time, place and manner (Kairos), and 2) that motivation in learning is more than just behavior change, it is a change of attitude as well, an active choice and commitment to participate (directly or peripherally) in learning activities. Thus, persuasive learning design transcends the original approach to the act of ‘teaching’ (as pure dissemination of knowledge) to an act of ‘pedagogy’, which is about scaffolding the child in developing skills and methods for obtaining knowledge through interventions tailored to his or her interests and spectrum of abilities and disabilities (Chaiklin, 2003). This pedagogic approach to persuasive designs for learning thus emphasizes the importance of the students’ motivation for learning, which as I argue above is not inherently “intrinsic” or “extrinsic” but contextually embedded and mediated by social relations and experiences of self-efficacy and self-determination.

### Triggers and Flow in Persuasion and Learning

In this relation, I find that a combination of Fogg’s Behavior Model (B. Fogg, 2009) and Mihály Csikszentmihalyi’s Flow Theory (Csikszentmihalyi, 1997) contributes to my understanding of the individual and contextual preconditions for motivation and thus persuasive learning designs. With the Behavior Model (figure 7) Fogg argues, that three elements: *motivation*, *ability* and *trigger* must converge for a behavior to occur, thus designers may attempt to identify which one is lacking if a specific target behavior is not being performed (B. Fogg, 2009).

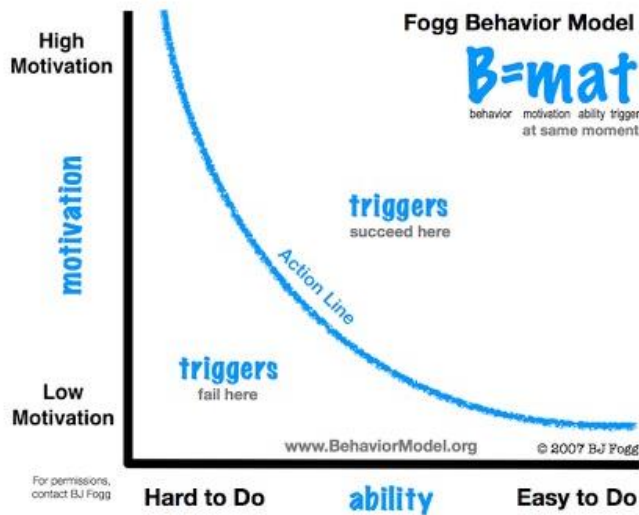


Figure 7: Fogg's Behavior Model (B. Fogg, 2009)

Although the Behavior Model to a certain extent resembles the somewhat simplistic, behaviorist view on motivation (outlining external factors as pleasure or pain, hope or fear and social acceptance or rejection as core motivators), it does approach a more design- and context-oriented perspective, since the effect of the trigger is mediated by the motivation and ability of the user to perform the target behavior. It also illustrates a tradeoff between motivation and ability, e.g. if motivation is very high, ability can be low, and vice versa (B. Fogg, 2009; B. J. Fogg, 2016).

Whereas Fogg's Behavior Model contributes to my understanding of Persuasive Learning Designs with the perspective on persuasion as mediated by motivation and ability, Flow Theory adds to the motivation-dimension in the model a certain complexity. To Csikszentmihalyi, motivation is not just a result of expected pleasure or pain, rather it is mediated by perceived challenges and skills to perform the activity (Csikszentmihalyi, 1997) and the state of "flow" is thus:

"...a subjective experience of engaging just-manageable challenges by tackling a series of goals, continuously processing feedback about progress, and adjusting action based on this feedback." (Nakamura & Csikszentmihalyi, 2014).

Under these conditions, experience seamlessly unfolds from moment to moment, and one enters a subjective state with intense concentration and a sense of capability, a merging of action and awareness and distortion of temporal experience, a loss of reflective self-consciousness and an experience of the activity as intrinsically rewarding (Nakamura & Csikszentmihalyi, 2014). In the original model, flow (e.g.

play, creativity) is experienced when perceived opportunities for action are in balance with the actor's perceived skills (Csikszentmihalyi, 1975). The current model of the flow state is even further detailed, describing not just the state of *flow*, *anxiety* or *boredom* but also states of *relaxation*, *control*, *arousal* and *worry* (figure 8):

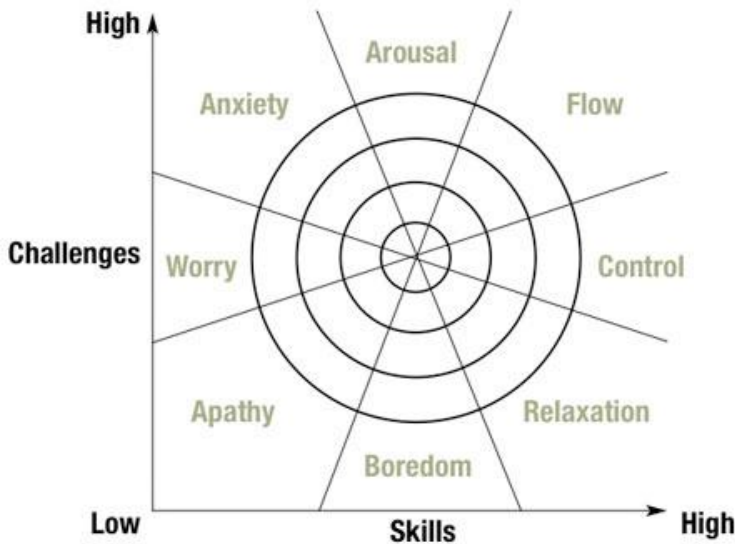


Figure 8: The Flow Model (Csikszentmihalyi, 1997)

Facilitating a state of flow is the ultimate goal of any Persuasive Learning Design, but inherently rare and intrinsically fragile. If challenges begin to exceed skills, the learner could become anxious and if skills continuously exceed challenges, the learner's relaxation gradually turns into boredom. The learner will attempt to adjust the level of skill and/or challenge in order to escape the aversive state of anxiety or boredom and reenter flow, thus shifts in subjective state (e.g. if the student disengages in the interaction) could provide essential feedback to the persuasive learning designer (in this case, teacher) about the balance between challenge and skill.

### Symmetry: The 'Control and Consensus'-Correlation

Whereas Fogg's Behavior Model explains how the effect of (external) interventions is mediated by (internal experiences of) ability and motivation, Flow Theory explains how (internal experience of) flow is mediated by the relationship between (internal experiences of) skill and challenge.

What the following 'Control and Consensus Correlation', initially introduced in (Bertel, 2010) and further elaborated in paper III and IV ((Bertel & Majgaard, 2014;

Bertel & Rasmussen, 2013a), adds to this, is the perspective that (internal experiences of) motivation/flow in connection to a learning design (e.g. a task) is not only defined by (internal experiences of) skills/ability and the characteristics of set task, it is also mediated by perceptions of social (i.e. external) aspects as well, such as the symmetry between the persuader and persuadee.

This approach is inspired by the Self-Determination Theory, which presents a general theory of human motivation as affected by social and cultural factors that facilitate or undermine people's sense of *autonomy*, *competence* and *relatedness* (Ryan & Deci, 2000) illustrated through a continuum ranging from *amotivation* (where people do not act at all or act without intent) to *intrinsic motivation* (where people do the activity for its inherent satisfactions). To illustrate this in a way comparable to that of Fogg's Behavior Model and Csikszentmihalyi's Flow Theory, rather than a linear continuum of self-determination, I have mapped out 'symmetry' as the correlation between perceived *control* (i.e. autonomy) and perceived *consensus* (i.e. congruence between the goals of persuader and persuadee) (figure 9):

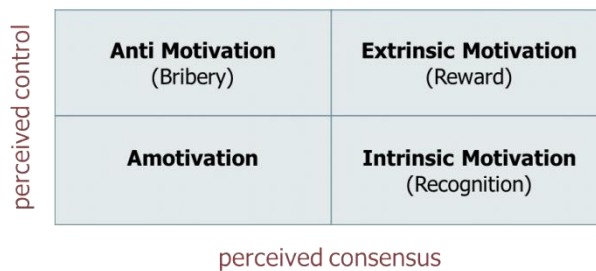


Figure 9: The 'Control and Consensus'-Correlation (Bertel & Rasmussen, 2013a)

This proposes an alternative explanation as to why triggers/incentives (e.g. rewards) might not always work. If experienced self-determination is low and perceived level of congruence equally low, a reward might come off as "bribery" having detrimental effects on motivation, whereas rewards given in contexts with high levels of perceived control and consensus may be considered more as recognition, thus having a positive effect on motivation (Bertel & Rasmussen, 2013a). Whereas the Behavior Model and Flow Theory seem to view skill/ability and motivation/challenge as independent of social context, I view motivation as socially situated (within a context of more or less symmetry). Since the educational context will always incorporate an inherent asymmetry between the persuader (teacher) and the persuadee (student), this may very well affect the results of a given persuasive learning design or intervention, which also proposes a possible explanation as to why motivation sometimes stay absent, even though the challenge of the task seem to match the learner's skills.

## B. EDUCATIONAL ROBOTICS

Educational Robotics as a term refers to robotic devices in schools mostly used in robotics-related courses in Science, Technology, Engineering and Math (STEM). Most often these are robotic kits, such as the Mindstorms robots (LEGO Mindstorms, 2016) or modular robots such as Dash & Dot (Wonder Workshop, 2016) or Fable (Shape Robotics, 2016). They are often highly adaptable, rebuildable, programmable (and affordable) and they are argued to facilitate experimentation, reflection, collaboration and motivation (Garcia & Patterson-McNeill, 2002; Lawhead et al., 2002; Majgaard, Misfeldt, & Nielsen, 2010; Matarić, Koenig, & Feil-seifer, 2007).



*Figure 10: Educational Robotics - LEGO Mindstorms, Dash & Dot and Fable*

Educational Robotics has many insights to offer when it comes to the pedagogy of robots in education. The constructionist approach to learning, which originated from and is inherent in the field of Educational Robotics (S. A. Papert, 1980) and its connections to experiential learning (Dewey, 1938) contributes to the concept of PEERs particularly with its perspective on robot-supported learning as the translation of abstract theoretical concepts through embodied interaction and experimentation (Alimisis, 2013; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013; Majgaard et al., 2010; Caprani & Thestrup, 2010) and encouragement of project-based learning (Resnick & Rosenbaum, 2013), its attention to participatory methods in educational robotics design- and development processes (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Hamner, Lauwers, Bernstein, Nourbakhsh, & DiSalvo, 2008; Majgaard, 2011) as well as its emphasis on applicability of the research to practitioners with practical advice and suggestions for exercises (Caprani, 2016; S. Papert & Solomon, 1972).

### **Tinkering and Objects-to-Think-With**

The outset of most learning activities involving educational robotics is the construction or adaptation of a robotic device and experimentation with coding this device. This method is also referred to as “tinkering”, characterized by a *“playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths and imagining new possibilities”* (Resnick & Rosenbaum, 2013:164). According to Resnick and Rosenbaum, although tinkering can be hard work, it is aligned with play. Whereas play is often associated

with entertainment, to Resnick and Rosenbaum it is a specific style of engaging with the world, a process of testing the boundaries and experimenting with new possibilities (Resnick & Rosenbaum, 2013: 165). From this perspective, learning in constructionism is thus very much about “making mistakes” and as such robots become “objects-to-think-with” in a process where the learner receives continuous feedback through trial and error (Majgaard, 2011):

“Many children are held back in their learning because they have a model of learning in which you have either “got it” or “got it wrong”. But when you learn to program a computer you almost never get it right the first time. Learning to be a master programmer is learning to become highly skilled at isolating and correcting “bugs”, the part that keeps the program from not working. The question to ask about the program is not whether it is right or wrong, but if it is fixable.” (S. A. Papert, 1980).

In the tinkering concept, the process of becoming stuck and unstuck is argued to facilitate a sense of authorship, purpose, and deep understanding of the materials and phenomena (Petrich, Wilkinson, & Bevan, 2013) and as such relates to the state of flow, as it describes a process or state, in which the students immerse themselves in the activity. However, as Resnick and Rosenbaum argues, the most tinkerable construction kit is only as successful as the context for tinkability, i.e. the supporting activities, materials, facilitation, space and community (Caprani, 2016; Petrich et al., 2013; Resnick & Rosenbaum, 2013). This is supported by studies reporting challenges and drawbacks from implementing robotic kits in education (Fagin & Merkle, 2002; McNally, Goldweber, Fagin, & Klassner, 2006) and research showing that educational robots should be supported by sound pedagogic models and methodologies, theoretical knowledge, well-designed tasks and well-suited work conditions (Marianne Lykke, Coto, Jantzen, Mora, & Vandel, 2015; M. Lykke, Coto, Mora, Vandel, & Jantzen, 2014).

In the context of PEERs, it is interesting to note the difference between this constructionist, tinker- and prosumer-approach to learning supported by educational robots and the behaviorist/cognitivist and the consumer-approach to r-learning robots that are considered ‘social’ (Han, 2010). Naturally, this is a result of differences in the features and affordances of the technology (e.g. whereas an element of “construction” is often implied with educational robots, social r-learning robots are usually not re-buildable/adaptable). However it might also have something to do with the framing of the target group, i.e. the enactment of specific groups of students as active/passive and able/disabled. Whereas educational robotics is used worldwide in education as a learning tool, it is surprisingly rare in special education, which in turn is overrepresented in social r-learning research (Karna-Lin, Pihlainen-Bednarik, Sutinen, & Virnes, 2006), and as argued in (Hansbøl, 2016) children with special needs such as autism could potentially benefit just as much from the role of the “doer”, controller or creator of the robot as from the assistance it may provide.

### C. PERSUASIVE (SOCIALLY ASSISTIVE) ROBOTICS

In the intersection between Persuasive Design and HRI are social robots designed to change attitudes and/or behavior and this persuasive ‘intention’ distinguishes regular Persuasive Robotics from HRI (Ham et al., 2011; M. Siegel et al., 2009; M. S. Siegel, 2008). Since it focuses on the strategies of robots as social actors, it is related to the existing field of Socially Assistive Robotics (SAR) which is considered the intersection between Assistive Robotics (e.g. rehabilitation robots and robots for the physically disabled) and Socially Interactive Robotics (Feil-Seifer & Matarić, 2005, 2011). Although SAR and Persuasive Robotics represent distinct research fields and approaches to social robots and behavior change, they do share similarities and common goals, thus I refer to the field as Persuasive (Socially Assistive) Robotics.

SAR was developed to address the multitude of important assistive tasks where social interaction rather than physical contact with the user is the central focus (Feil-Seifer & Matarić, 2005). In the initial introduction of SAR in 2005, one of the main areas of application was post-stroke rehabilitation (Matarić, Eriksson, Feil-Seifer, & Winstein, 2007; Tapus & Matarić, 2008), however today SAR aims to address supervision, coaching, motivation, and companionship aspects of one-on-one interactions with individuals from various large and growing populations, including stroke survivors, the elderly and individuals with dementia, as well as children with autism spectrum disorder (Feil-Seifer & Matarić, 2011). The SAR framework (figure 11) adds to the original SIR taxonomy (figure 6) the following properties:

<i>Properties</i>	<i>Description</i>	<i>Example</i>
User population	can address various populations of users (age, impairments, needs)	Elderly, children, users with physical/ cognitive disorders
Task	engages the user effectively, achieves domain-specific goals and addresses needs of direct users and indirect stakeholders	Tutoring, physical therapy, assistance, communication
Interaction modality	interacts through multiple modalities (separate from ‘personality’, describing the reciprocal user interaction as well)	Speech, Gestures, Direct input (screen)
Role	defined by the task it is assisting with, the user population and the impression it gives through its appearance and behavior	Care-giver, therapy aid, toy

*Figure 11: Additional SAR properties to the SIR taxonomy (Feil-Seifer & Matarić, 2005)*

As I argue in paper I (Bertel, 2013), these taxonomic additions somewhat specify the overlap between persuasive design and HRI, since having a predefined user group and task entails a specific intention within the design. What Persuasive Robotics adds to this, is specification of the persuasive strategies that a socially assistive robotic agent might utilize and attention to the psychological effects interacting with such agent might have on humans (Hammer, Lugin, Bogomolov, Janowski, & André, 2016; Midden & Ham, 2012; M. Roubroeks, Ham, & Midden, 2011b; Midden & Ham, 2009; Ham & Midden, 2009) as well as ethical considerations that arise when the robot might have goals or intentions potentially incongruent with the user's (Ham & Spahn, 2015; M. a. J. Roubroeks, Ham, & Midden, 2010).



*Figure 12: Persuasive (Socially Assistive) Robots – NAO, PARO, iCat and Reeti*

From a PEERS perspective I find that the taxonomic additions of SAR adds context and complexity to Fogg's original principles of persuasive social actors, providing a framework for evaluating and prioritizing these components in relation to the context of the interaction, which I further elaborate in paper III (Bertel & Rasmussen, 2013a). I argue that the taxonomic additions describe the benefits that robots have in the intervention when compared to humans, such as the use of different interaction modalities (text, audio, image, speech and gesture), or the ability to assume different roles depending on the user and task. However, it should be noted that the human teacher is in many ways equally capable of utilizing such strategies (using different modalities and assuming different roles in the interaction). What I would argue, though, is that social robots might be more easily and naturally (almost intuitively) enacted as peers and companions within contexts of inherent asymmetry (such as education), which I attempt to document in paper IV and V (Bertel & Hannibal, 2016; Bertel & Majgaard, 2014).



## PEER UP!

The distinction between different ‘roles’ of robots in interactions I find particularly useful in understanding the persuasive power of social robots in interventions. However, the property is somewhat vaguely defined in the SAR taxonomy “*by the task it is assisting with, the user population it is working with and the impression it gives through its appearance and behavior*” (Feil-Seifer & Matarić, 2005). Naturally, from a PEERs perspective the role as a ‘peer’ is particularly interesting and as mentioned earlier gaining increasing attention in HRI and social robotics research. The persuasiveness of a social robot in the role as a peer seem to be associated with its ability to align behavior e.g. through grounding, mutual goal-setting and shared goals expressions (Breazeal & Scassellati, 1999; Breazeal, 2003, 2009; Kanda et al., 2004; Hammer et al., 2016), through emotional expressions (Ginevra Castellano et al., 2010; Leite et al., 2012; Leite, Martinho, Pereira, & Paiva, 2008) and distinctive features of speech, gestures, positioning or posture (Zaga et al., 2015) or by providing the user with the possibility to assume a role (e.g. as a caregiver) that is otherwise unattainable (Klein et al., 2013; Lammer et al., 2014; Tanaka & Kimura, 2010).

Whereas researchers have been exploring social robots as peer tutors in education for a while (Kanda et al., 2004), the learning by teaching paradigm with robots have originally focused on the robots’ ability to learn rather than the beneficial impact on human learning (Werfel, 2013). The concept of care-receiving robots and its application to reinforce (particularly pre-school) children’s ‘learning by teaching’ was proposed by Tanaka and Kimura in 2009 (Tanaka & Kimura, 2009, 2010). The approach is argued to be both ethically sounder and accelerating spontaneous active learning e.g. in English vocabulary training (Tanaka & Ghosh, 2011), reporting on the emergence of different forms of learning-by-teaching; *direct teaching* (i.e. taking the robot “by the hand” and leading it step by step), *gesturing* (i.e. demonstration of procedure by body movements) and *verbal teaching* (i.e. giving vocal instructions) (Tanaka & Matsuzoe, 2012a) and emphasizing the robot’s actual ability to learn as having an impact on the children’s learning ability as well (Matsuzoe & Tanaka, 2012). Other research focus on the possible improvement of children’s self-confidence and motivation promoted by the behavior of the learning robot (e.g. in relation to handwriting skills (Hood, Lemaignan, & Dillenbourg, 2015; Jacq, Garcia, Dillenbourg, Paiva, & others, 2016) and on the presence of a robot facilitator as motivating and making children teaching other children feel more responsible for these children’s learning (however not necessarily improving learning gains) (Chandra et al., 2015; Short et al., 2014). Yet other research focus on the caring behavior of children towards a social robot in need of help (Ioannou, Andreou, & Christofi, 2015).

Whereas researchers in cHRI seem to agree that social robots as peers support motivation, attention and learning (Zaga et al., 2015, 2014), it should be noted that the persuasive potential of a robot in a ‘frail’ position (in need of care, assistance or teaching) is also contextual. For instance, in a study with college students, being the recipient of caregiving acts from a robot lead users to form more positive perceptions of the robot than being an ostensible caregiver to the same robot (K. J. Kim, Park, & Sundar, 2013) and in a study on intelligent trash barrels in public spaces, “struggling behavior” (such as getting stuck and bumping into things) had a polarizing effect on bystanders, with about one half finding it embarrassing and annoying and the other finding it endearing and adorable (Fischer et al., 2015). Also, as mentioned earlier, in most cases the robot’s need of assistance or care is “staged”, it is orchestrated with Wizard of Oz methods as a social role rather than a technological reality and the current and inherent insufficiency of the technology itself has not been explored as a potential facilitator of motivation in (social) HRI.

From a persuasive design perspective, the initial (and changes in) attitudes towards robots are naturally interesting. This is not completely new HRI research, which have explored particularly cultural differences in attitudes towards educational robots, however mainly from a student, parent or public perspective (Choi, Lee, & Han, 2008; Han et al., 2009; Lin, Liu, Chang, & Yeh, 2009; Liu, 2010; Reich-Stiebert & Eyssel, 2015; Shin & Kim, 2007). Some studies also include the views of teachers, however in most cases the evaluation of attitudes relates to reflections on hypothetical situations (E. Lee, Lee, Kye, & Ko, 2008; Reich-Stiebert & Eyssel, 2015) and in the few cases where reflections relate to actual experiences with robot-supported teaching and learning, the teachers have (with a few exceptions, e.g. (Jones et al., 2015) usually not been involved in the process of developing the robot-supported designs for learning that they are evaluating (Baxter et al., 2015; Kory Westlund et al., 2016). What persuasive learning design and design-based research contributes to this is the understanding that contextual factors (such as the teachers’ attitudes towards and engagement in robot-supported learning designs) mediates their effects and as such, persuasion takes place at two levels; the students engagement in learning and the teachers engagement in professional development. Thus, ‘Peer up!’ refers just as much to researchers’ partnership with practitioners as it refers to students companionship with social robots.

My contributions to cHRI research in these different aspects are thus theoretical reflections on how robots as peers might be particularly motivating within (asymmetrical) educational contexts (paper I and IV), a methodological approach to the development of PEER-supported designs for learning in collaboration with teachers (paper II), empirical analyses of examples of such learning designs in practice (paper III) and analytical perspectives (e.g. articulation, imitation and dynamic categorization) as tools for interpretation of the role of the robot in the interaction and its effect on interaction, motivation and learning (paper V).

## CHAPTER 3. PEERS AT PLAY

The thesis contains three independent case studies in different (and diverse) educational settings: autism therapy and education (My Pal PARO), health education in formal and informal learning settings (KRAM NAO) and cross-disciplinary STEM projects in primary and secondary education (FutureTech). In the case studies, I used existing robotic platforms; the zoomorphic PARO seal and the humanoid robot NAO. An alternative approach, perhaps more true to the original DBR and participatory approach, could have been to collaboratively design and develop a new robotic prototype with practice through the case studies. However, the proportions of even confined aspects of such development would itself equate to a PhD and thus shift focus entirely from the principles of teaching and learning with a robot to the technological challenges of building one. As DTI demonstrates and distributes both PARO and NAO, these robots were conveniently available to me with the technical support needed and since I wanted to avoid Wizard-of-Oz methods in the study, I had to choose robots that were preprogrammed/autonomous (such as PARO) or programmable by novices and/or children (such as NAO). Finally, these platforms are also the most commonly used social robots in Denmark, so ideally the results of the case studies should be relevant and applicable to many teaching and learning environments outside the contexts of the case studies.

### CONDUCTING CASE-STUDY RESEARCH

From a methodological point of view, the cases all share the position that interactions with the robots should be investigated over time and in real-world settings and that the relationship between researchers and practitioners should be one of symmetry. By this I mean that I did not have particular predefined applications that I wanted to ‘test’. The PEER-supported learning designs were very much user-driven, developed and explored iteratively and collaboratively in partnership with practitioners. Whereas the case studies share similarities, they also vary in time (duration), space (location) and symmetry (between researcher and practitioners). Future-Tech was the longest in terms of total duration (6 months), however the users changed with 8 week-intervals. My Pal PARO was the longest with the same users (3 months). KRAM NAO was the shortest (2 months) and somewhat a serial-short term study, since the robot was not staying at the school between lessons. My Pal PARO was the least restrictive in terms of space, since the teachers could bring the robot wherever they wanted, and the robot did not require any particular setup (wires or computers) to function. All case studies emphasized symmetry between researchers and practitioners, however in both KRAM NAO and FutureTech the participation and project management of external partners did affect the ‘freedom’ of the users to some extent, since they naturally had a certain goal or agenda with initializing the project in the first place.

## CASE 1: MY PAL PARO

This first case study took place in the fall of 2012 at a special needs (primary) school for children with autism in the northern part of Denmark. The school receives students from the entire region (around 60 students divided by age and level of cognitive and communicative skill). The case study took place in three classes with 6-8 students and 2-3 teachers each. Although the students are divided in teams by age; Team1 (6 children aged 6-9), Team2 (7 children aged 10-13) and Team3 (8 children aged 14-17), they were at a similar level of cognitive development (estimated by the school as equivalent to 0-1 years of age<sup>6</sup>).

The PEER platform in the project was the robotic seal PARO, which is autonomous and capable of simulating the sounds and movements of a baby harp seal. It is argued to increase the quality of life for nursing home residents, e.g. by reducing stress and anxiety and providing people the opportunity to care for something/one (Wada, Shibata, Saito, Sakamoto, & Tanie, 2005; Wada, Shibata, Saito, & Tanie, 2004). In Denmark, at least 210 PAROs have been implemented, mostly in dementia care but also with adults with developmental disorders or acquired brain injury (Klein et al., 2013). Some research suggests that PARO can also be used to facilitate social interaction among children with autism (Patrizia Marti, Lund, Rullo, & Nielsen, 2004; P. Marti, Pollini, Rullo, & Shibata, 2005; Roberts & Shore, 2013).

After a meeting with the headmaster, psychologist and a teacher representative, the school chose the groups of students for the study based on ideas and expectations about what the students might gain from interacting with PARO. The group defined the overall goal of the project as exploring the potential of using PARO to facilitate communication, social interaction, play and learning. In early September I was invited to introduce myself and PARO at a meeting with all teachers to get feedback on initial ideas and thoughts on the project. Prior to the initiation of the case study, a letter with information about me, PARO and the project as well as an informed



*Figure 13: Interacting with PARO*

<sup>6</sup> It should be noted that the assessment of 'cognitive age' is difficult and that individual differences exist within the group. Older students (age above 13 years) were more self-sufficient in daily life activities such as going to the bathroom, eating lunch and getting dressed to go outside than younger children. With a few exceptions, most had no or very little spoken language and used alternative tools for communication such as pictograms or sign language (Bertel, Rasmussen, & Christiansen, 2013).

consent form was provided to the parents of the participating children. With this contract, the parents allowed their child to take part in the study and to be recorded on video, which could be used for papers, presentations and teaching.<sup>7</sup> The school handled this process, which they were quite familiar with, since they were already using video recording as part of their pedagogic and professional development.

In October the PARO robots were delivered to the school and the basic functionality of the robots introduced to the teachers. As I explain in paper II (Bertel et al., 2013) the DBR-setup comprised three exploratory phases with different follow-up activities which can be summarized as follows:

1. Phase I (*exploration phase*)
  - a. Introductory meetings (brainstorming) – *all teachers*
  - b. Commitment and goal-setting – *teaching teams and management*
  - c. Delivery of the PARO robots
  - d. 2-3 weeks exploration (breadth > depth) – *teachers/students*
2. Phase II (*co-ideation phase*)
  - a. Cross-team workshop (knowledge sharing) – *team representatives*
  - b. 2-3 weeks assisted exploration (breadth > depth) – *teacher/students*
  - c. Team meetings (sharing and redefining goals) – *each team*
3. Phase III (*co-creation phase*)
  - a. 3-4 weeks assisted exploration (breadth < depth) *teachers/students*
  - b. Cross-team workshop/plenary (focus group interview) – *teachers*
  - c. Dis/continuation / phase-out<sup>8</sup>

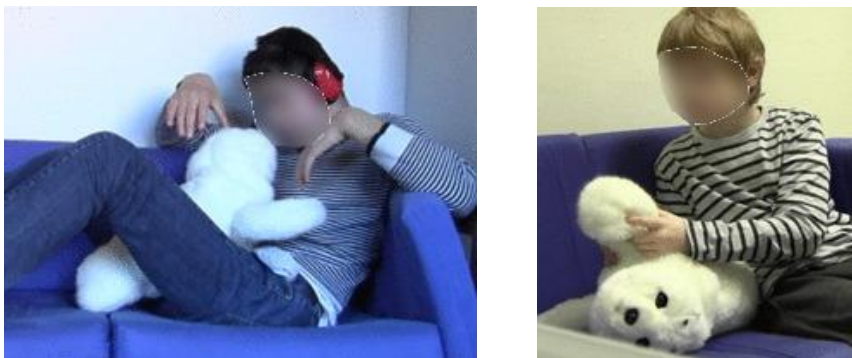
I visited the school weekly throughout the project period and participated in both PARO and non-PARO related activities to get insights into the context of the case study and an idea about everyday practices, possibilities and challenges within this particular environment. PARO-related activities included one-on-one interactions between PARO and a child, joint attention activities with PARO between two or three children as well as group interactions. In most cases these activities were supported by one or more teachers. Non-PARO related activities could be individual and collaborative curriculum-related tasks (e.g. solving puzzles, drawing etc.) or breaks such as going for walks, eating lunch or spending time at the computer. Other activities could be the children going to physical or music therapy or teachers’

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<sup>7</sup> The names of the children, teachers and school have been anonymized in papers and presentations to protect the identity of those involved.

<sup>8</sup> Upon initiation of the case study it was important to me to add this continuation/phasing-out of the project because of the possibility of the children forming very strong attachments with the robot and thus the risk of a strong reaction to it ‘leaving’ the school. Luckily, this turned out not to be an issue in this case. However, during this phase we did plan and applied for funding to continue the collaboration.

meetings to get feedback from the psychologist and communications counsellor. I also met with the IT supervisor who offered to collect all the PARO-related videos the teachers were recording. Apart from these videos, data consisted of my own observational notes and video recordings, in situ interviews I conducted with teachers (and children to the extent that it was possible) during the phases and a concluding focus group interview with the teachers involved.



*Figure 14: One-on-One Interactions with PARO*

In the first cross-team workshop (step 2a) a teacher from each team and the school's headmaster participated. They shared early experiences (video clips and stories) about their students' first interactions with PARO and came up with ideas and suggestions for each other to further explore PARO. For instance, one teacher showed a video of a child singing to PARO and a video of three children and herself dancing with PARO. This inspired another teacher to bring PARO to her music lessons. The third teacher explained how one-on-one interactions with PARO in their team was on each child's schedule like all daily activities, which was also considered useful to the other teams. One teacher talked about one of the children's first encounter with PARO and a surprising extension of this child's attention span (from usually less than 5 minutes on one activity to about 20 minutes, though somewhat decreasing as the child became more familiar with PARO). Another teacher gave an example where PARO was redirecting attention in a stressful situation; one of the students would get very anxious when she had to interact with people she did not know well, however when they had borrowed one PARO from one of the other teams, she had the job of returning it, which encouraged her to approach and interact with the other teams' teachers and students. This story inspired one of the other teachers to consider using PARO with a student who had difficulties with staying 'on task' or 'in the moment'. Generally, the teachers reported that particularly the children with a little language and communication capabilities were benefitting the most from interacting with PARO, and inviting other students to take part in the interaction as well.

Ideas for new learning designs from the workshop were discussed and explored in each team. This resulted in a more systematic use of PARO (in two of the teams with a reduced student group) in the final phase (step 3a) of the study. In the concluding focus group interview all the involved teachers participated. They evaluated PARO's applicability to their context and made suggestions for further development of the robot. They argued that more opportunities for individualization of the robot's reactions and communication patterns could be useful, for instance when teaching 'appropriate' interactions with animals (PARO did not react differently to heavy-handed treatment, which a real seal or dog probably would). They also would like more accessories for the robot, but some had themselves creatively designed a carry cot and picked out grooming accessories together with students. They agreed that PARO was particularly useful in directing and redirecting attention in stressful situations such as staying on task, going to new places or meeting new people. They discussed the match between the robot and this particular group of students (some suggested it could be useful for students with more communicative abilities) and they reflected on how working with the robot had initiated new insights into their own pedagogic practice. For instance, one teacher reflected that it had made her realize that "managing" interaction e.g. through turn-taking rules was sometimes disrupting the very initiative for social interaction she was trying to facilitate.



*Figure 15: Joint-Attention Activities with PARO*

The My Pal PARO case study contributed several things to my understanding of PEERS. First of all I gained insights into the complexity of a specific educational context, which seem to be of particular interest within the HRI community. The benefits of DBR when trying to capture contextual factors such as embedded knowledge and practices for knowledge-sharing, the social relations and stakeholder values which mediate technology use is documented in more detail in paper II under the headlines: *knowledge*, *social relations*, *values* and *flow* (Bertel et al., 2013) with particular attention to the adjustment of research setups and innovation processes according to the ecology of the context. In the paper, I refer to the TSS-framework as the methodological approach enabling me to do this, however as I argue in chapter 2, the TSS-grid serves better as a categorizing of different methodological approaches to empirical HRI studies, of which the DBR can be considered one.

Furthermore, I gained insights into the applications of PEER-supported learning in autism education from the perspectives of the teachers, which I report in paper III (Bertel & Rasmussen, 2013a) and (Bertel & Rasmussen, 2013b). In these papers, I argue that the contribution of the robot to the interaction can be viewed either from the perspective of the *objective* of the interaction which in this case mostly relates to facilitating different types of *attention* (i.e. bodily and verbal attention, joint attention, social group attention or re-direction of set attention) or from the perspective of the *role* of the robot, e.g. sensory cognitive stimulant, object of joint attention or as a companion in certain difficult situations (figure 16). Finally, it contributed to the development of PEERS with the understanding of the educational context as one of asymmetry, which I elaborate in paper IV (Bertel & Majgaard, 2014).

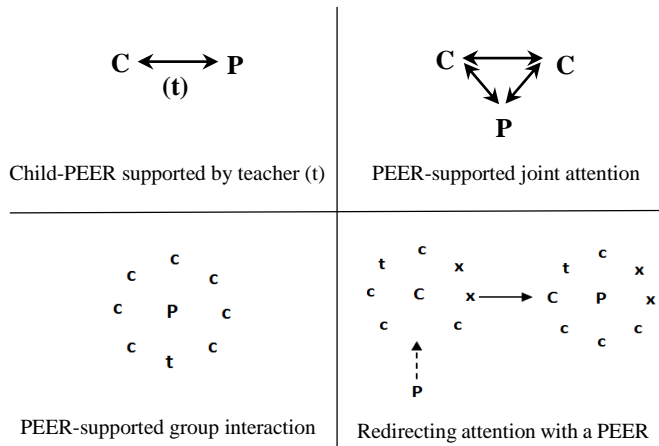


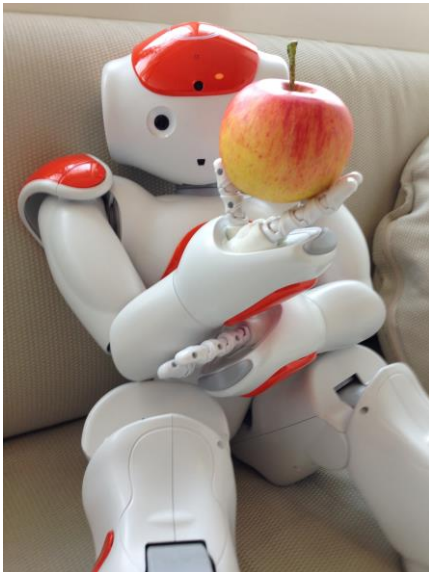
Figure 16: The roles of a PEER in PEER-supported Learning (Bertel & Rasmussen, 2013b)



## CASE 2: KRAM NAO COPENHAGEN

The KRAM NAO Copenhagen (KRAM NAO) project took place from October to December 2013 and was led by the Municipality of Copenhagen (Health and Care Administration) with technical support from DTI. KRAM is an acronym for Kost (diet), Rygning (smoking), Alkohol (alcohol) and Motion (exercise) (Statens Institut for Folkesundhed, 2008) and in Danish meaning both “hug” and “high quality”. The purpose was to explore the potential of using advanced, interactive technology to create new communities of play and learning within a context of health promotion in a neighborhood characterized as socially and economically disadvantaged. The project was initiated on a need for action in the health education field to strengthen young people's knowledge of and attitude towards their own health and public health issues in general, while also addressing the issue of preparing young people for a technological future as critical consumers and co-producers of technological artifacts. Thus, the project involved students in robot-supported knowledge- and development processes in which they jointly and actively worked with and disseminated current health topics related to the KRAM-factors in new ways through advanced, interactive (robot) technology. Two different schools (one public, one private) participated (2 teachers and approximately 40 7<sup>th</sup> grade students).

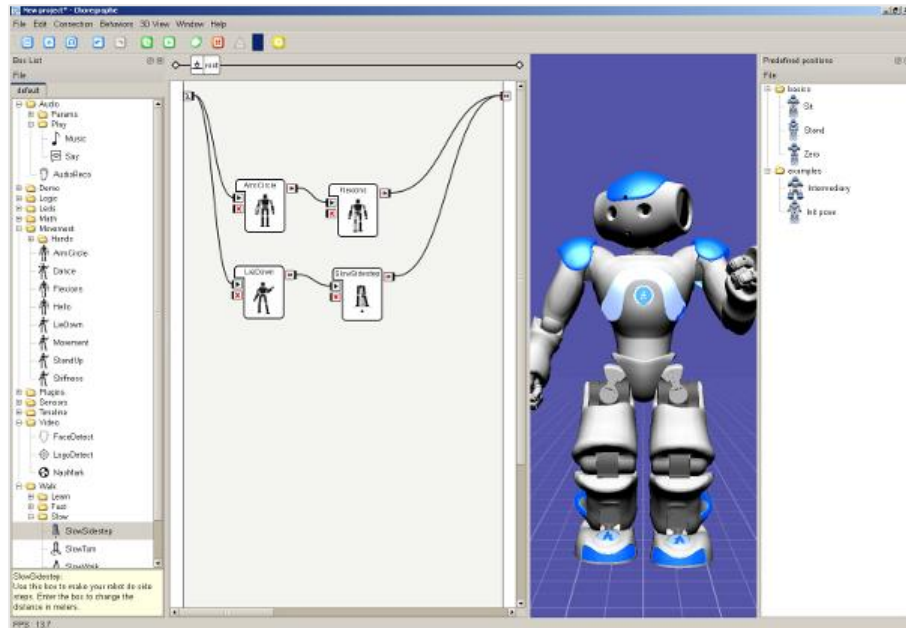
The NAO robot, developed by French Aldebaran Robotics in 2006, is a small humanoid, aiming to reflect the concept of a human being with human-like features



*Figure 17: The NAO Robot*

and affordances, without attempting to ‘accurately’ resemble the human body (like android or geminoid robots). It is 58 cm tall and equipped with microphones, cameras, tactile and pressure sensors, allowing some simulation of perception (i.e. being “reactive” by “looking for” and responding to words and gestures). It communicates through movement (25 degrees of freedom) and speech (19 different languages) as well as colored LED lights in its eyes. It is programmable in ‘Choregraphe’ (a visual drag-and-drop language) as well as Python and C++ for experienced programmers. Choregraphe consists of a series of easy to understand predefined modules (e.g. “Say,” “Stand Up,” “Go to” etc.) combined in sequences and executed in a virtual 3D environment or on the physical robot.

In several of the modules it is possible to enter values (coordinates, degrees or distances) and text (to-speech). It has an ‘animation’ mode, enabling physical programming similar to industrial robotics’ programming-by-demonstration which requires almost no prior technical training (Danish Technological Institute, 2014).



*Figure 18: The Choregraphe Programming Interface*

NAO was developed mainly as a research platform, however increasingly used as a teaching aid, particularly in STEM teaching in secondary and higher education and according to Aldebaran Robotics, more than 70 countries now use NAO in computer science classes from primary school through to university (Aldebaran Robotics, 2016). As I mention in paper V (Bertel & Hannibal, 2016), Denmark was one of the first countries to start using NAO in primary school (Frank, 2013; Majgaard, Hansen, Bertel, & Pagh, 2014). Choregraphe’s visual programming interface allows novices to program it, and it is even being introduced in preschool in some Danish cities (Sørensen, 2015). Currently, more than 90 NAO robots are in use at all levels of the educational system for purposes as diverse as the inclusion of children with special needs in primary school (Greve Kommune, 2015) and the development of talented high school students with specific interests in robotics (ScienceTalenter, 2015). Whereas NAO is being introduced in education in several countries (Aldebaran Community, 2015), the focus on primary school children programming NAO themselves is to my knowledge still quite unique to Denmark.



*Figure 19: Activities in the KRAM NAO Copenhagen case (Bertel, 2014)*

The KRAM NAO case study started up with a technical introduction to NAO and a workshop with a teaching consultant, the Health and Care Administration representative, and teachers, IT-supervisors and some student representatives from the two schools in order to generate ideas and goals for possible robot-supported designs for learning and health promotion. Ideas included developing communication products, interactive games, storytelling, quizzes, knowledge catalogues and playful exercises. Based on the workshop, the project manager developed a learning design focusing on the visual communication and the combination of NAO with storytelling techniques. From a DBR perspective, the case did not as such involve an exploration phase, but proceeded directly to the co-ideation and co-creation phases.

A typical example could be that students sought information about one of the public dietary guidelines, developed a design or dissemination plan (e.g. a play, presentation or commercial), coded NAO in Choregraphe and presented their work in a short video, which they edited and shared on YouTube. In such learning designs, NAO mediated student-to-student production and dissemination of health knowledge. This required collecting and processing data and transforming it into a communication product, which required health literacy, design- and communication competences and technical skills including video recording and editing techniques. In addition, it would enable the students to learn about programming and explore NAO's abilities (e.g. movement, grasping, audio and video signal processing and object recognition).



*Figure 20: KRAM NAO Copenhagen design products in progress (Bertel, 2014)*

The students were divided in two groups at each school (8-12 students each) and organized in teams of 2-3 students each. The learning design was a 4-week course with one 3-hour lesson each week for all four groups. The first lesson was mainly Choregraphe-related technical training and the second lesson was mainly health-related. In the two final lessons, the students developed and planned their concept, programmed, video recorded and edited. The courses were handled by the Health and Care Administration representative in cooperation with the teachers involved.

There were several differences in the courses between the two schools. At the public school, participation was optional across different classes, whereas at the private school, an entire class enrolled in the project and participation was obligatory. The voluntariness at the public school, which I visited weekly throughout the project,

meant that not all students attended each lesson making it somewhat difficult to plan sessions ahead. However, enabling students to go to and from courses and other activities in or outside school also meant that some of the students were motivated to continue work at home in their spare time or show up early in the morning to work on their projects. The students presented their productions to each other, consultants from DTI and the Health and Care Administration as well as representatives from the urban renewal group in the area at a closing event at the local library in week 51.

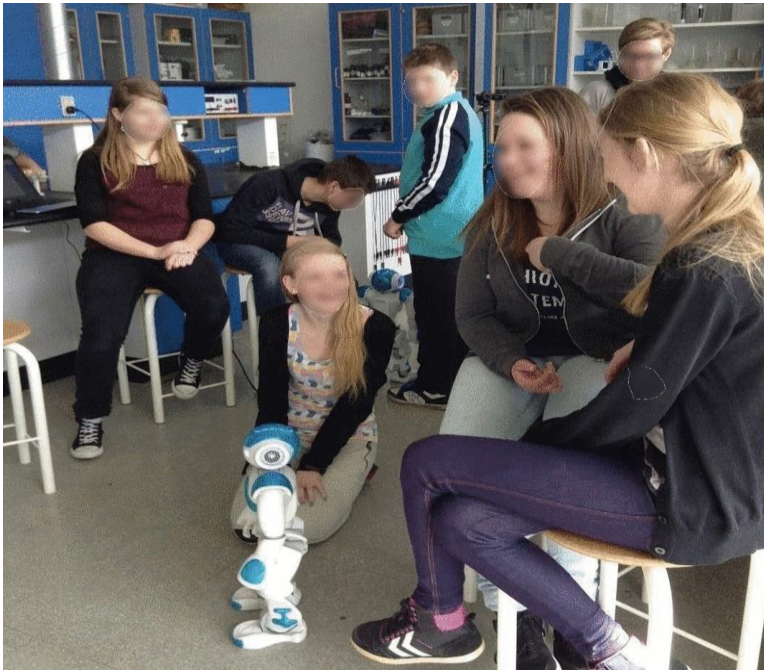
To assess the potential of robot-supported health promotion, a pre- and post- survey focusing on health was conducted by the Health and Care Administration. The private school also worked with 'diet diaries' in the initial phase of the project to increase students' awareness of their own eating and exercising habits. As I used the project as a case in my industrial PhD project, my focus was on NAO's potential to motivate learning, which I investigated primarily through observation, in-situ interviews and a few video recordings. Additional data included students' logs and productions as well as a concluding questionnaire focusing on the experience of interacting with the robot (and each other) and self-assessment of technological, collaborative and communicative skills throughout the project.

The outcome of the project was a technical report (in Danish) analyzing surveys and student logs as well as observations and interview statements. In the survey, the students reported thinking more often about healthy eating habits after the course, and were also able to name more of the health recommendations compared to prior to the study. Interestingly, more students reported eating healthy prior to the course compared to after, which could indicate that they became more aware of their dietary habits. Whereas it is difficult to assess whether a potential for behavior change could actually transcend the context of this particular course, the results seem to indicate at least, that working with dietary diaries and dissemination of health recommendations can increase attention towards one's habits. Furthermore, from a motivational perspective, it was interesting to notice the students making a distinction between 'having fun with NAO' and 'learning with NAO', which I hypothesize could stem from the asymmetry in the context. Although the children generally enjoyed working with NAO, they also found the connection to health somewhat far-fetched. Ideas from strengthening the connection between content and form can be found in the children's own suggestions for robot-applications in education, which emphasizes students younger than themselves as an ideal target group. From this perspective, having a target group or recipient of the student-developed learning designs could possibly facilitate motivation. In addition to the survey results, the study also showed that the level of abstraction (i.e. the students' ability to use, utilize, reflect upon, design and develop with the technology) and thus level of learning (e.g. Biggs, 2011; Bloom, 1956) was quite high. The project report, which is included in the paper collection (part 2) also presents findings on *learning objectives and academic achievements, technology understanding and play in learning*) as well as the potential for increasing a *sense of community* within the area, which was a parallel goal in the project.



### CASE 3: FUTURETECH

The FutureTech project (in Danish, FremTek) was a collaboration between Insero Science Academy, researchers at University of Southern Denmark and DTI in the school year of 2013/2014 (Insero Science Academy, 2013).



*Figure 21: Teacher and students working with NAOs (Bertel & Hannibal, 2016)*

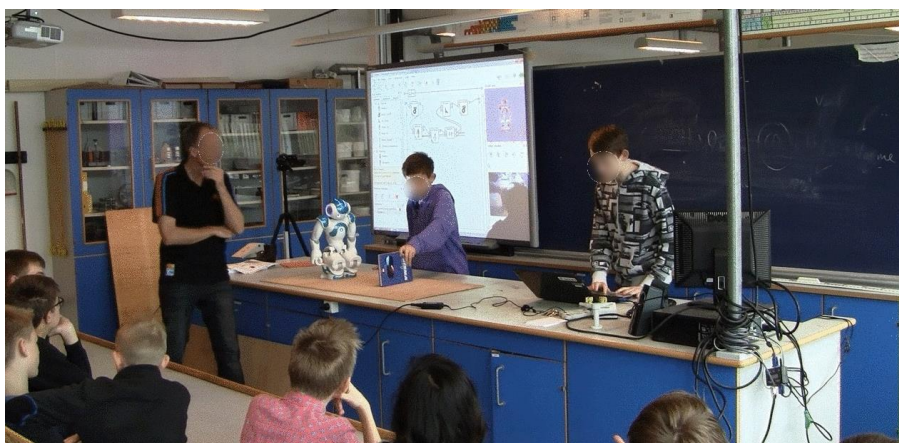
The purpose of the project was to explore advanced technology (robots and 3D-printers<sup>9</sup>) to enrich educational environments and support teaching, and to understand what planning and preparation such technology-supported learning designs require (Majgaard et al., 2014). Like the preceding case studies this project was based on the Design-based Research approach and the project involved three iterations over the course of a year (with different participants in each iteration). In each iteration, 3-4 classes worked with NAO at their school for 5-6 weeks, at a minimum of 8-10 hours (maximum was 20 hours) in total. Whereas it could be argued that the overall process of the project involved the three DBR phases described in case 1 (exploration, co-ideation and co-creation), each group of teachers only took part in one iteration which involved the following activities, as described in paper V (Bertel & Hannibal, 2016):

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<sup>9</sup> In the following description I will focus on activities involving the NAO-robots.

1. A two-day workshop for teachers
  - a. Day 1: Hands-on experience with NAO. Each teacher brought two students to this technical session
  - b. Day 2: Development of learning designs and lesson plans based on a model developed by Hansen (Hansen, 2012)
2. Practical application of the NAO-supported learning designs (each class had access to a set of three NAO robots and eight PCs with Choregraphe).
3. Follow-up visit(s) by researchers and Insero
4. Written evaluations from teachers (open questionnaire)

Based on each round of teaching experiments, experiences and feedback, the workshop design was re-iterated and improved. For instance, in the first workshop it was difficult for the teachers to define learning objectives with NAO, thus in the following workshops the teachers were presented with examples and best practices from prior participants (Majgaard et al., 2014). Also the support of ‘super-users’ (i.e. inviting two students to participate in the technical session) was only a suggestion in the first workshop, whereas it was highly recommended in the following iterations based on positive feedback from prior participants. Based on analyses of the two first rounds, for the final iteration (which was managed by Insero) we suggested adding an ‘exploration phase’ (e.g. 1-2 weeks) between the technical and didactic workshops in which the teachers could explore NAO with students and colleagues prior to defining learning objectives. Data included observations, video, in-situ and focus-group interviews with students as well as a final written teacher-evaluation. We also provided the teachers with an optional questionnaire for the students, however few teachers included it in their evaluation. All participants had access to each other’s lesson plans and evaluations through a designated wiki-page.



*Figure 22: NAO- ‘super users’ introducing the robot to their classmates*

During the project, I visited one 3<sup>rd</sup> grade class, two 7<sup>th</sup> grade classes and an elective high school science and technology course. Observations from 3<sup>rd</sup> grade and high school are reported in (Majgaard & Bertel, 2014). I followed each of the two 7<sup>th</sup> grade classes more closely together with co-supervisor Gunver Majgaard and colleague Glenda Hannibal, to understand how NAO could support cross-disciplinary teaching (Majgaard et al., 2014) and to understand children's framing of NAO and discuss differences between articulations when actively working with robots compared to post-reflection (paper V, (Bertel & Hannibal, 2016)).

In the first 7<sup>th</sup> grade class, 24 students worked with three NAO's for five weeks, 2-4 hours per week (the robots were available at the school throughout the 5 weeks). NAO was part of a cross-curricular course involving two teachers in science and Danish, respectively. The teachers initially ran separate lessons; a short technical course where the students completed programming assignments (making NAO move and avoid obstacles, speak and recognize images); and a poetry course. Thereafter, knowledge and skills from the two courses were merged and the students had to create 'future'-themed poems performed by NAO. In groups of four they analyzed and discussed poems and collaboratively wrote their own, and programming NAO to perform for a final presentation in plenary (Majgaard et al., 2014). During the course, the two student 'super-users' from the hands-on workshop were responsible for setting up NAO and assisting their fellow students with programming questions. Other students were responsible for setting up and collecting the computers.

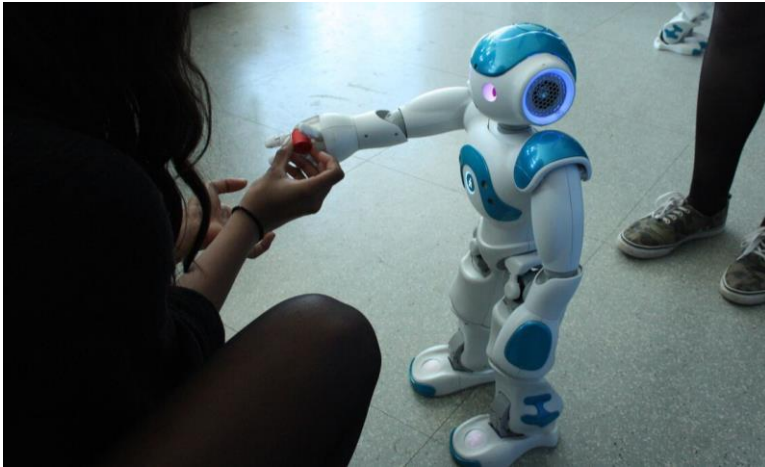


*Figure 23: Students imitating NAO (Bertel, Rasmussen, & Majgaard, 2015)*

As we describe in (Majgaard et al., 2014) the teachers argued, that the very specific task requirements led to synergy between technological literacy and academic goals. Having experimented with and learned the basics of programming NAO, the very specific task seemed to spark creativity and motivation for action, and the clear requirements and fixed boundaries of the task seemed to provide rather than limit opportunities for expression. We observed that they were exploring many of the functionalities in the programming interface (e.g. the animation mode) and the Danish teacher reported that working with the robot-performance motivated the students to “dive deeper” into their poems, through iterations of experimentation,



adjustment and refinement. This description is similar to the “tinkering” process (Resnick & Rosenbaum, 2013) which in this case extended beyond the technical-practical work and into academic reflection. As such, NAO became an object-to-think with in this poetry- and programming example. In contrast, teachers who concluded the technical course with very open-ended tasks experienced students getting “stuck” or complete the task quickly, just meeting minimum requirements. Whereas we did not focus particularly on social aspects of the NAO-supported learning designs in this case, we did observe that the students were in many ways engaging in or simulating social interaction with NAO (e.g. seeking eye contact, addressing it by name and imitating its gestures). Thus, in the second 7<sup>th</sup> grade case we aimed more directly at understanding if students experienced NAO more as a tool, simulating medium or social actor, and whether this was consistent across contexts or dynamic as suggested by Kahn and colleagues (Peter H. Kahn Jr. et al., 2011; P. H. Kahn, Freier, Friedman, Severson, & Feldman, 2004). These findings and analyses of key examples are included in paper V (Bertel & Hannibal, 2016).



*Figure 24: 7<sup>th</sup> grade student working with NAO*

The Future-Tech case studies provided several insights into the potential and challenges of applying social robots in education. First of all, they documented that most children (as young as 9 years old) are able to understand basic (visual) programming with very little training. The programmed behaviors were not particularly complex, however as Brooks suggests (Brooks, 1986; Majgaard, 2011) the complexity of the context seemed to add complexity to the children’s experience of the technology. The case studies also indicated, that the robot did not have to perform perfectly to be a platform for tinkering and reflection. In fact, in several cases it was the robot in the position as ‘frail’ or in need of assistance that motivated interaction and engagement.

From a PEERs perspective, the contextual factors (*knowledge, values, social relations* and *flow*) that I had identified in My Pal PARO contributed to my understanding of NAO as a PEER in this context as well. In relation to the ecology of the teaching environment (*flow*), resources (which in many cases involved different technologies) and digital literacy affected the approach to and success of the learning design. Time was a scarce resource, and the teachers were very aware of their obligation to ‘document’ learning in relation to the Common National Guidelines. The teachers’ evaluations of the potential for inclusion of weaker students, I found provided insights into the contextual assessment (*values*) of the quality of participation and learning. The teachers argued, that working with NAO in many cases provided these students with new roles and *social relations* (i.e. as ‘more knowledgeable others’) and that they would be very active and engaged in the programming-part of the course, but ‘return’ to their normal status and level of engagement once they were met with “academic” requirements. This suggests a very specific understanding of *knowledge* and its acquisition (i.e. what can be considered ‘academic’), which is challenged by Papert’s constructionist approach to learning (S. A. Papert, 1980). I will further discuss these findings and their implications to the development of PEERs in chapter 5.

## ETHICAL CONSIDERATIONS

My approach to ethics in is informed by ontological ethics (Løgstrup, 1956) and its applications within persuasive and participatory design (Gram-Hansen, 2016; Gram-Hansen & Gram-Hansen, 2013; Gram-Hansen & Ryberg, 2016). In this research, the ontological (or *constructive*) approach to ethics is considered a supplement to ethical evaluation, which in contrast to deontological or utilitarian approaches emphasize ethicality as something intuitive and highly contextual (Gram-Hansen & Ryberg, 2016). As such, this approach rejects reducing ethicality to rules concerning ethical or unethical actions or the consequences of such actions as it argues that the ethicality of any action must be assessed by the individual performing set action in a given situation. From this perspective, a persuasive technology is not by definition ethically sound if it is designed “without coercion or deception” or if it affects more people in positive ways than negative, rather it is affected by contextual factors such as the physical surroundings and activities that influence the power balance between those taking part in the interaction. Due to the intuitive nature of this approach, it does not as such replace traditional ethical evaluation. Rather it is a standpoint, a point of reference, when conducting research (or any other activity) that informs decisions and emphasizes values and the intuitive experience of ethicality in human conduct.

Hence, it was important for me not to preplan the studies entirely (relying on deontological principles of rights and obligations) but allow for decisions to be made and changed in context, based on my own and the teachers’ intuitive experiences of what was ethical in the specific situation at hand. This sensitivity was particularly important in the My Pal PARO case, since I was not able to communicate directly

with the children. For instance, whereas I had signed consent forms with regard to video recording, I ended up using mainly observational notes and interviews with teachers in most situations (only documenting that instances of interaction had actually taken place), since the children were not actually able to subsequently withdraw consent. However, as the teachers had much more personal experience with the children and professional experience in using video with these children, they were equipped to assess this particular aspect of ethicality moment-to-moment. This also meant (e.g. inspired by the probing-tradition (Gaver, Dunne, & Pacenti, 1999) that I relied on the teachers' own analyses and evaluations of their PEER-supported learning designs, taking their utterances at face value, which also was the case with the 'KRAM NAO' and Future-Tech projects.

As I mentioned in the introduction and also address in paper V (Bertel & Hannibal, 2016), my experiences with children's interactions with and reflections on robots in the case studies as well as in prior research made me question the critical take on robotic 'simulation' prominent in some areas of HRI research (e.g. (Turtle, 2007, 2011)). However, I was very aware of the children's possible emotional attachment to the robot (particularly PARO due to its seemingly autonomous simulation of affection and attachment) and had planned a phasing-out of the robot to ensure that no child was so attached to the robot, that taking it away would be a violation, and I was committed to help the school raise funding for the PAROs if this was the case. Even though it turned out not to be an issue in this case, I do recognize the importance of considering aspects of simulation and its possible implications, particularly when working with children or people with cognitive impairments (or very convincing social robots). In My Pal PARO the children seemed aware that PARO was no ordinary electronic toy (for instance, they would repeatedly check if they could elicit a specific behavior in the robot by touching or squeezing in a certain way). However, they also seemed aware that it was not alive. For instance, one child who was very afraid of pets and animals, was not at all afraid of PARO, whereas another child who was very fond of dogs, did not think much of PARO. Although my analyses do not attempt to explain why this is the case, it illustrates that (at least in the initial encounter) PARO does not inherently and independently belong to any particular category of known objects and artifacts. The same is the case with NAO.

Thus, although children in my opinion in general are perfectly capable of adjusting their expectations in relation to the robots performance, abilities and inadequacies, I still argue that acting ethically in relation to the interaction between robots and children (and any other user group for that matter) implies presenting the technology as honest and straightforward as possible. If a researcher wish to investigate children's take on the future of social robots (i.e. robots with abilities that exceed the current), rather than applying Wizard of Oz methods to simulate such abilities, I would just ask about their honest opinions on the matter. In my experience, children's level of reflection on this matter is generally very well developed.



## CHAPTER 4. PEER REVIEWED

As mentioned in the introduction, the thesis contains five published research papers included in a separate publication. The following chapter is thus an attempt to summarize, reflect and comment on the contribution of each paper. As I have referred to the papers where relevant throughout the dissertation, the focus here is to clarify how each paper address different aspects of my research questions and in what ways they have contributed to my journey as a developing researcher. My multi-disciplinary approach to PEEERs is reflected in the collection, which is a mix of conference (3) and journal papers (2) published in very different communities and domains including HRI and HCI, Persuasive Technology and the Learning sciences.

### **PAPER I: PERSUASIVE EDUCATIONAL AND ENTERTAINMENT ROBOTICS (PEERS)**

This paper was based on an extended abstract for the 1<sup>st</sup> AAU Workshop on Human-Centered Robotics in Nov. 2012, which aimed to provide a platform for exchange and collaboration across AAU faculties and departments. The workshop was highly multidisciplinary with presentations about medical robots, social robots and HRI, innovative robot design, control and vision technologies. Around 50 participants from AAU, SDU, DTI and industrial companies attended. The proceedings contain 7 selected full papers reviewed by an external board of international reviewers.

The paper is mainly theoretical, introducing the concept of Persuasive Educational and Entertainment Robotics (PEERs) and presenting my initial reflections regarding the combination of Persuasive Design as it is presented in the early work of B. J. Fogg (B. J. Fogg, 2003) and Socially Interactive Robotics as introduced by Fong, Nourbakhsh and Dautenhahn (Fong et al., 2003). I outline the basic principles of these theoretical frameworks and discuss their strengths and shortcomings and how they contribute to the development of PEERs. In addition, I reflect on behaviorism, cognitivism and constructivism as three main understandings of motivation and learning and argue PEERs as representing particularly the constructivist approach.

My focus in paper I is the idea of PEERs as something “in between” the socially engaging teacher and the persuasive (mostly screen-based) teaching technologies and an opportunity to access and technologically mediate motivational strategies that are otherwise associated with and limited to human-human interaction and persuasion. I hypothesize that one important aspect is the distribution of roles between PEERs and humans (i.e. the robot being the receiver rather than provider of care, teaching etc.) and consider on a theoretical level the possibility of using social robots to “break down” otherwise rigid, social constructions and structures and create new relations and ‘knowledgeable others’.

At this point, though, I was yet to initiate my empirical work and although I had a few early experiences with cHRI, the review of the theoretical principles of persuasive design, HRI and learning was too general to provide guidelines applicable to real-world PEER design- and implementation processes. Also, my knowledge of learning theories was still very basic at this point and particularly research related to Educational Robotics and constructionism was limited, thus I was not yet able to fully unfold this aspect of the concept. However, as I maintain this overall theoretical concept throughout the thesis, I realize that many of the ideas for further theoretical and empirical exploration was already beginning to take shape in this early work. This includes reflections about Socially Assistive Robotics as the intersection between persuasive design and HRI and the strategic choice of components as the contribution of persuasive design to HRI, and vice versa, which I later unfold in paper III. It also includes pre-empirical reflections about the distributions of roles between robots and humans, which I further explore in paper V as well as the alignment of motivations and goals in contexts otherwise inherently asymmetrical (paper IV).

## **PAPER II: ROBOTS FOR REAL: DEVELOPING A PARTICIPATORY DESIGN FRAMEWORK FOR IMPLEMENTING EDUCATIONAL ROBOTS IN REAL-WORLD LEARNING ENVIRONMENTS**

This paper, co-authored by Dorte Malig Rasmussen and Ellen Christiansen, was written in connection to the ‘My Pal PARO’ case study. The paper was accepted for presentation at the 14<sup>th</sup> International Federation for Information Processing (IFIP) Conference on Human-Computer Interaction (INTERACT) in September 2013 and published in the LNCS Springer Series. The conference theme was ‘Designing for Diversity’ and the paper was presented in the session ‘Humans and robots’.

The purpose of the paper was, in part, to discuss methodological issues in HRI and particularly in HRI studies involving children; and in part to present methodological aspects of my own case study as a possible framework for participatory design in HRI and cHRI studies. In the paper I refer to Han’s (2010) distinction between educational robotics (i.e., hands-on robotic kits) and r-learning service robots (i.e., social, anthropomorphized robots) and emphasize differences in the traditional methods applied in these research fields, particularly the degree to which users seem to be involved in design- and implementation processes. As part of the introduction, I discuss some of the challenging issues I believe are present with the traditional HRI methods, including:

- 1) Ethical and practical issues in relation to Wizard of Oz methods
- 2) Reliability and replicability issues, e.g. limitations in duration and location of experiments and the hypothesis-based research’s units of analysis (i.e. ‘correlations’ over ‘interpretations’ and ‘quantification’ over ‘qualification’)

- 3) Applicability issues in relation to the dominant preference for generalization (standardization) over individualization (which is problematized in educational research in general, and special education in particular).

It should be noted, of course, that these issues arise partly from epistemological differences in my own constructivist approach to human inquiry and the post-positivist paradigm apparent in many HRI studies (the logic of which are somewhat inherent in the technical sciences and to some extent reproduced in the social sciences' and psychological approach to HRI studies as well). Based on these reflections, I present my own case study design as a possible participatory design framework for involving users in the development of robot-supported learning designs in practice. I term this framework Time-Space-Structure or TSS and discuss different contextual factors (knowledge, social relations, values and flow) that this framework revealed in my research.

As I mention in the introduction, I renamed the TSS-framework 'Time-Space-Symmetry' to better capture its essence (i.e. the 'symmetry' or power balance between researcher and subject) and revised it into a generic, visual representation of different methodological approaches to HRI, the 'TSS-grid'. Whereas I would argue, that the TSS-grid could guide a systematic review of HRI methods in general with particular attention to the research questions that specific TSS-correlations might attempt to address, this is considered outside the scope of this thesis and one possible direction for future research. The contextual factors identified in this framework, however, have guided and informed my take on the NAO case studies as well, which is also reflected in the Future-Tech case study description above.

### **PAPER III: ON BEING A PEER: WHAT PERSUASIVE TECHNOLOGY FOR TEACHING CAN GAIN FROM SOCIAL ROBOTICS IN EDUCATION**

This paper, co-authored by my co-supervisor Dorte Malig Rasmussen, was accepted for the special issue on Persuasive Technology for Teaching and Learning of the IGI Journal of Conceptual Structures and Smart Applications in October 2013 (available January 2014). It is a continuation of a paper (Bertel & Rasmussen, 2013b) for a workshop on Persuasive Technology for Learning, Education and Teaching (IWEPLET) held in conjunction with the European Conference on Technology Enhanced Learning (EC-TEL) in September 2013. In that paper, I analyzed and presented the empirical findings from the My Pal Paro case study mainly from a Persuasive Learning Design point of view, since this was the theme of the workshop. The primary focus of paper III is a PEER point of view on the specific intersection between persuasive design and learning with particular attention to the notion of 'persuasive social actors for learning' and to the potential contribution of social (assistive) robotics to the further development of Fogg's notion of social actors.

Furthermore, in this paper I reflect on the traditional educational context as one of implied inequality and discuss its implications, i.e. the inherent and embedded social relations as a condition for persuasive interventions. This characterization I later refer to as the ‘context of asymmetry’ (paper IV) (Bertel & Majgaard, 2014). The purpose is to discuss the original persuasive principles of social actors within such a context against related theories and taxonomies of technologies as social agents (including robotics) as well as findings from the case study, and to try to extend these into design guidelines for persuasive social actors in the context of teaching and learning.

The initial analysis of the empirical data presented in the workshop paper centered on attention (bodily, verbal and social) and the robot’s ability to direct or redirect attention in certain critical situations. In the first part of paper III, I analyze these findings with particularly attention to the role of the robot and the relationship between the robot and the child. In the second half of the paper, I analyze these persuasive robot-supported learning designs from a Socially Assistive Robotics (SAR) point of view as presented by Feil-Seifer and Mataric (2005). I find that the taxonomy of SAR enriches and contextualizes the original persuasive principles of social actors and increase their applicability to practice. Thus, the following suggested revision of the original persuasive principles of social actors I consider the main contribution of paper III:

<b>Persuasive principle</b>	<b>SAR</b>	<b>Extended Principle</b>	<b>Design Guideline</b>
Attractiveness Similarity	User	Strategic design of appearance /behavior	Match the physical design of social actors to the user population and their preferences (sometimes being similar to/different from the user)
Reciprocity	Task	Strategic selection of tasks	The tasks of social actors should be of value to users (consensus) and preferably intrinsically motivated (control)
Praise and rewards	Modality	Strategic feedback	Feedback from social actors should match users’ physical/cognitive/social abilities, and depending on role provide praise and rewards (recognition)
Authority	Role	Strategic design of social roles	Social actors should be able to assume different roles depending on the user, task and context, e.g. the role of the receiver of care, assistance, tutoring etc.

*Figure 25: Extended Principles and Design Guidelines for Persuasive Social Actors*



## **PAPER IV: PERSUASIVE EDUCATIONAL AND ENTERTAINMENT ROBOTICS (PEERS) - ALIGNING ASYMMETRIC INTERACTIONS IN EDUCATION**

This paper, co-authored by co-supervisor Gunver Majgaard, was accepted for a highly multi-disciplinary workshop on ‘Humans and Robots in Asymmetric Interactions’ held in conjunction with the 9th International Conference on Human-Robot Interaction (HRI) in 2014. Whereas paper III focused on the contributions of HRI and Socially Assistive Robotics to Persuasive Designs for teaching and learning, this paper conversely focuses on the contributions of Persuasive Design and Learning (particularly educational psychology) to HRI and social robots in education. It builds on the theoretical framework of PEERs and adds a more detailed presentation of Self-Determination Theory as introduced by Ryan and Deci (2000), which I briefly touch upon in paper III. I try to explicate the theory’s contributions to my understanding of motivation and the context of education (and particularly special education), as one of asymmetry. I go into more depth with specific aspects of my analysis and map motivation as a function of perceived control and of perceived consensus.

In the paper, I look more into related work on positive and negative feedback and its persuasive potential as well as robots in the role as instructors (tutors). I refer to the work of Park, Kim and Pobil (2011) showing that feedback from a human instructor is in some cases considered more acceptable when compared to feedback from a robot and the work of Roubroeks, M. A., Ham, J. R., & Midden (2010) arguing that dominant behaviors in robots can cause psychological reactance. This is in line with the extended principle “Strategic Design of Social Relations” developed in paper III (Bertel & Rasmussen, 2013a) which suggests that robots are not necessarily persuasive as instructors and should sometimes assume different roles when facilitating motivation and alignment depending on the user population. This is supported by research from Tanaka and colleagues (2011 and 2012) indicating a persuasive potential of social robots in the role as “student” rather than teacher.

The paper’s concluding section contains some of my reflections on state-of-the-art in social robotics, the current limitations of the technology and its inferiority with respect to physical, cognitive and social capability and its persuasive (motivational and relational) potential in education (rather than a source of error to be avoided using Wizard of Oz methods), which is something that I continue to explore in the following case studies (reported in paper V) and consider a key finding of my thesis.

## **PAPER V: THE NAO ROBOT AS A PERSUASIVE EDUCATIONAL AND ENTERTAINMENT ROBOT (PEER) – A CASE STUDY ON CHILDREN’S ARTICULATION, CATEGORIZATION AND INTERACTION WITH A SOCIAL ROBOT FOR LEARNING**

Whereas the previous papers report mainly on the My Pal PARO case, this paper, co-authored by Glenda Hannibal, accepted for a special issue on Robotics in the electronic journal Learning and Media (LOM) on the use of ICT for learning, competence development and cooperation (available January 2016), reports findings from the Future-Tech case study (specifically the second 7<sup>th</sup> grade class we visited) particularly in relation to the potential of NAO as a PEER. Other papers on this case include (Bertel et al., 2015; Hannibal, 2014; Hansen, 2016; Majgaard et al., 2014).

The outset for this paper was observations of contextual differences in children’s application of gender pronouns to NAO (Hannibal, 2014). Thus, in this paper we explored conceptual categorization in relation to Fogg’s categories (tool, simulating medium or social actor) based on articulation and embodied interactions with NAO. We found that although the children seemed to intuitively categorize NAO as a social actor, this was mediated not only by contextual factors (e.g. working actively with NAO or post-reflecting in interviews) but also by the performance of NAO. We found examples of shifts in categorization (e.g. from social actor to tool) when the robot failed to meet (social) expectations in specific situations (e.g. stalling, delaying, freezing and falling) and the children initiated social repairs to try to “justify” or add meaning to the interaction breakdowns (shifting categorization back to that of a social actor). We also found breakdowns to facilitate iterative observation, experimentation and critical reflection, making NAO an object-to-think-with (Papert, 1980).

Finally, we argue that active simulation, i.e. (un)conscious *framing* or *narration* (e.g. as a baby or football player), *imitation* and *rehearsal of social concepts* (e.g. “appropriate” greeting-behavior) could be glimpses into children’s intrinsic motivations and thus could provide teachers, designers and researchers ideas about how to facilitate engagement in NAO-supported learning activities. While it does not appear from the paper, this particular finding facilitated a re-iteration on the organization of the teachers’ technical course and subsequent workshop, since it emphasized the importance of incorporate these active simulations triggered by the robot particularly in initial interactions, into the learning designs. Thus for the final Future-Tech iteration (managed by the project partner Insero) we suggested at least a two-week interval between technical course and the didactic workshop, in which the NAO robots should be made available to the teachers for experimentation (and ideally workshops with the students as well). From this perspective, rather than a collection of persuasive strategies, Fogg’s categories offer a perspective on the learner’s experiences and conceptual understanding of the robot (or any technology), which is essential in development technologically mediated designs for learning.

## SUMMARY OF MY CONTRIBUTIONS

Each paper in the dissertation contributes to the development and refinement of the PEERs concept and my understanding of the persuasive potential of robot-supported learning designs. Additionally, the papers illustrate a progression; through my understanding of the concept's theoretical underpinnings and through my empirical investigations and thus experiential learning cycle as a developing researcher.

The papers all explore subareas of the stated research goals (p. 17), thus, whereas paper I specifically addresses the theoretical conceptualization of PEERs and paper II particularly explores methodological aspects of the concept, the empirical papers (III, IV and V) all inform and further develop the applicability of the concept to practice. Furthermore, paper III and IV contributes to the research goals with theoretical aspects of motivation as mediated by social relations and the context of education as one of asymmetry and paper V discusses the role of the robot in relation to specific forms of learning. Whereas Paper III and IV analyses PEER-supported learning designs from the teachers' perspective, paper V focuses on interaction, motivation and learning from the perspective of the student. In summary, the papers contribute to the research questions with the following main findings:

- 1) Children seem to intuitively react to and categorize social robots as social actors, however interaction does not have to remain 'fluent' or uninterrupted for motivation and learning to occur
- 2) Children are capable of adjusting their expectations towards social robots rather quickly and accurately in response to experiential learning cycles of observation, experimentation and reflection in and on action
- 3) Social robots in 'frail' positions seem to elicit intuitive caring behavior in children (anywhere on the spectrum of ability and disability)
- 4) The taxonomy of Socially Assistive Robotics adds context and complexity to the persuasive principles of social actors. On the other hand, persuasive design adds ethical considerations to the framework as it emphasizes the implied intention (and intervention) in any 'assistive' technology
- 5) A constructivist/constructionist approach to learning contributes two things to PEERs: an understanding of the social context of any learning design as inherently asymmetrical, and the role of the robot in the learning design as a subsequent enactment of the role of the child - as either a consumer or co-producer of technological practice.

As these insights are situated in the specific intersection between Persuasive Design, Human-Robot Interaction and learning, the theoretical contributions are considered particularly relevant to researchers in the Socially Assistive Child-Robot Interaction community (e.g. related to special education, robot-assisted therapy etc.) and to researchers in Persuasive Designs involving (embodied) social actors/agents (in or outside the education domain) as well as researchers in Educational Robotics considering the motivational and educational potential of robots with social features and affordances. In addition, the Time-Space-Symmetry Grid and my methodological findings particularly related to the contributions of Design-Based Research (DBR) to HRI could support and guide the research agenda promoting long-term, user-centered approaches to HRI studies ‘in the wild’ with the following findings:

- 6) The DBR approach provides the opportunity to continuously adapt and individualize robot-supported learning designs to the context and the user
- 7) The DBR approach provides insights into contextual factors affecting implementation (i.e. knowledge, social relations, values and flow)
- 8) Users and practitioners are valuable partners in both exploration, co-ideation, co-creation and evaluation phases of HRI
- 9) An initial *exploratory* phase provides insights into the user’s intrinsic motivation and thus can guide the further design- and development process

As a collection of case studies, these findings naturally have certain limitations. They could be isolated incidents, not applicable to or replicable in other educational contexts, with different users or different robots. However, as I argue in chapter 2, the intention of this thesis is not to present a ‘general’ theory of social robots in education, or to question or qualify one specific of the many theories put forward in the Social Robotics and Persuasive Design communities. The purpose of the case studies is to develop and refine a guideline for (one particular approach to) the process of developing robot-supported learning designs in practice, and propose possible explanations through examples, observations and analyses about how these designs may affect interaction, motivation and learning. Thus, whereas debunking the myth that smooth, uninterrupted interaction should be preferred in cHRI can be considered one outcome of the case study (consistent with related research suggesting e.g. that negative outcomes of dominant robot behavior is further enhanced by increasing social cues (M. a. J. Roubroeks et al., 2010; M. Roubroeks et al., 2011a) or that social interaction might even in some cases distract from learning (Kennedy, Baxter, & Belpaeme, 2015), the purpose is not propose an alternative, generic theory (e.g. stating that cHRI should always be disruptive) but rather to emphasize the *potential* of exploring new approaches different from what we are used to and accept as somewhat common sense.

# CHAPTER 5. PEERS IN PERSPECTIVE

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*“The world needs all kinds of minds”  
(Temple Grandin, 2010)*

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In this final chapter, I would like to return to Dr. Temple Grandin, who inspired me to see my overall field of inquiry ‘social robots as mediating artifacts in education’ in a different light; not only evaluating their persuasiveness as social actors and tools to support learning, but exploring their potential to uncover and complement children’s spectrum of abilities and facilitate change in educational environments.

In the past three years, I have had the opportunity to explore this potential of such robots in practice together with teachers (with different approaches to robots, technology and teaching) and students (with a range of abilities and disabilities) in diverse and highly complex educational contexts. As I emphasize throughout the dissertation, the concept of Persuasive Educational and Entertainment Robotics (PEERs) is indeed “work in progress”, and design principles and guidelines derived from theoretical and empirical inquiry will have to be subjected to continuous refinement through future interventions and iterations. Thus, my intention in this chapter is not to propose a universal model or theory of persuasive social robots in education, but to discuss and position my observations, experiences and analyses in relation to macro-level issues such as digital literacy, 21<sup>st</sup> century skills, ICT for inclusion and the future of education in a robotic society.

## **TEACHING 21<sup>ST</sup> CENTURY SKILLS: LEARNING ABOUT, WITH OR FROM ROBOTS?**

As robots continue to spread across society, robots will and should to a greater extent enter the educational arena as well. However, there is a big difference between viewing robots as something children could learn *about*, *with* or *from*, which is related to our understanding of robots as tools, mediators or social actors but also of *learners* as either consumers or prosumers (Han, 2010; Hansbøl, 2016).

Until now, the dominant application of robots in education mostly considers learning *about* robotic technologies as a subject, and the ability to design, build and operate robots is viewed as an important 21<sup>st</sup> century skill (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; Johnson et al., 2015; E. Lee et al., 2008; Shin & Kim, 2007). The general assumption, though, that widespread integration of ICT and media in teaching activities automatically create new generations of digital natives have been refuted (Bundsgaard, Pettersson, & Puck, 2014; Hjorth, Iversen, Smith,

Christensen, & Blikstein, 2015; OECD, 2015). Thus, I would argue that the pedagogy of learning *with* robots is equally important. As Bundsgaard emphasizes, 21<sup>st</sup> century skills are more than just knowing about technologies. It is a framework that analyses the competences needed for future citizens to navigate society, in terms of communication and collaboration, knowledge configuration, self-dependence and self-evaluation (Bundsgaard et al., 2014). For robot-supported learning designs to contribute to the development of these skills, they must be grounded in realistic issues and support creativity, critical thinking, communication and collaborative problem-solving based on articulated learning goals (Bundsgaard et al., 2014; Fullan & Langworthy, 2014; Johnson et al., 2015), which is also what is emphasized as the particular strength of problem-based learning (Marianne Lykke, Coto Chotto, Mora, Svendsen, & Jantzen, 2014; Marianne Lykke et al., 2015).

When it comes to *social* robots as teaching technologies, though, the focus has initially been on children (and particularly children with autism) learning *from* robots (providing r-learning services such as teaching materials, assignments and instructions to students) (Han, 2010). Although the role of the robot as tutor or peer may differ (Belpaeme et al., 2012; Jones et al., 2015; Kanda et al., 2004; Leite et al., 2012; Matsuzoe & Tanaka, 2012; Mubin et al., 2013; Tanaka & Kimura, 2010; Tanaka & Matsuzoe, 2012a; Zaga et al., 2015), in most cases smooth interaction (without interaction breakdowns or disruptions) is considered a prerequisite (hence the Wizard of Oz methods). Although r-learning research does include social aspects (and as such constructivist perspectives) of teaching and learning, it also to some extent replicates the traditional teaching set-up, relying solely on the scaffolding of students by a more ‘knowledgeable other’ (in this case, robot). This somewhat narrow take on robots e.g. in special needs education might overlook the potential that a constructionist approach to learning *with* robots might have with this specific group (Hansbøl, 2016). A constructionist approach to learning implies creating space for unexpected ways of thinking. Thus, if unexpected robot behavior is considered only a source of error tarnishing the user experience, its potential as a source of reflection and problem-solving skill development might be overlooked. This is also the case with NAO, which is often used as either a purely programmable ‘tool’ (e.g. in science teaching) leaving out its social features, or only with preprogrammed “correct” social behaviors (e.g. in special education). In my opinion, combining the social and programmable features offers the child a glimpse into technical and practical issues as well as theoretical and philosophical questions of sociability, HCI and HRI, which I consider just as important as the technical, and as such a crucial 21<sup>st</sup> century skill.

## WHITE-BOXING SOCIAL ROBOTS

The current state-of-the-art in social robotics is somewhat “in-between”. Researchers’ end goals (e.g. scenarios where well-designed, fully functional and “flawless” robots engage in social interaction without technical support) are still hypothetical, and research focuses on how it *could* (and possibly will) be, and having

flawed and unfinished prototypes and beta-versions of set technologies supported by preprogramming or Wizard of Oz methods and tele-operation to sustain user experience - subjecting social robots to black-boxing (Waelbers, 2011). Indeed, these questions are relevant, and we need to imagine future scenarios where robots are fully autonomous and intelligent and people possibly replaceable in order to explore ideas, technological possibilities and ethical issues in such scenarios. However, this in-between state may cause researchers and particularly practitioners to find themselves in somewhat of a vacuum between what the robots are able to do, and what we *want* them to do. Although it is important from both a technological-, user- and societal viewpoint to try to predict these scenarios, my research suggests that the current state is by no means a vacuum when it comes to learning. Particularly, when teaching the children and young people whom we expect to develop the autonomous and intelligent robots of tomorrow, the technology's immaturity and imperfections might indeed be the very thing that sparks motivation to pursue a career in the field.

As argued e.g. in (Alimisis, 2013; Blikstein, 2013; Mitnik, Nussbaum, & Soto, 2008) preprogramming and "black boxing" robots in learning activities is based on the misconception that construction and programming is by definition too demanding to educational contexts, which is very different from constructionist methodologies that recommend a transition to the design of transparent ("white-box") robots where users can program, construct and deconstruct robotic objects (or robot-mediated narratives as argued in paper III and V). The focus here is on robots as facilitators of creative thinking, involvement and motivation in learners, rather than ready-made (passive) technological products somewhat comparable with the traditional curriculum book (Alimisis, 2013; Resnick, Berg, & Eisenberg, 2000).

In my empirical work the robots' 'frailty', flaws or failures were evident to me as well as to the teachers and students and what I discovered was that in reality, these flaws reveal a potential, i.e. as "objects to think with", tinker around with, become 'stuck' and 'unstock' with (Petrich et al., 2013). In contrast to many black-boxed technologies, immaculately designed and well-tested before reaching their users, I have had the opportunity to explore social robots in their current state, endearingly flawed and "unfinished". Based on my findings, I believe great educational potential can be found in social robots, *because of* their limitations, not in spite of them. That is, these robots frustrate and disappoint us - but also puzzle, charm and fascinate us. The interplay of these processes could challenge and change routines, encourage continuous experimentation, observation and reflection. Thus, the value of the unfinished and flawed lies in its potential to facilitate new ways of teaching and learning, new ways of thinking. From this perspective, the current messy state-of-the-art in social robotics could provide an optimal moment for intervention, nestled between what *was*, i.e. where social robots were not yet available, and what (probably) *will be*, i.e. where technological advancement and increasing corporate commercialization could possibly black-box them.

## TO ENGINEER OR NOT TO ENGINEER...

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*I began to see how children who had learned to program computers could use very concrete computer models to think about thinking and to learn about learning and in doing so, enhance their powers as psychologists and as epistemologists.*  
(S. A. Papert, 1980: 23)

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The origin of the word ‘engineer’ as derived from the Latin words *ingeniare* (“to contrive, devise”) and *ingenium* (“cleverness”) emphasizes the fact that *engineering* is just as much about novel methods and approaches to problem-solving as it is about technical skill. It is ‘tinkering’ around a problem, and *creating a clever solution*.

As tinkering is about evolution rather than reproduction, applying the methods of engineering to education entails a transformation of the rules of the context, in this case the classroom. Children need to engage with materials to understand them, and in this sense, playful and spontaneous interaction can be just as valid as traditional lecturing. Teachers in the FutureTech case reported on such transformation of rules, roles and relationships between teacher and students. As I explained in chapter 3, particularly the students who had participated in the technical introductory course as ‘super users’ were in many ways ‘the more knowledgeable other’. Students were helping each other, looking up questions online and sharing tips and tricks. Some teachers made their non-expert position explicit, exploring issues together with the students or directing them to the super users for advice. The organization of the physics classroom with open and levelled workspaces (the workbench and the floor) seemed to support this symmetry in the interaction, and the ‘super user’ was generally considered a good concept, relieving the teachers from practical/technical concerns while also supporting the super-users’ self-image and sense of belonging.

Some teachers noted that it was difficult to identify relevant learning objectives when planning robot-supported learning designs, whereas other teachers and ICT managers argued the opposite, emphasizing it as a matter of “engineering” (your interpretation of the Common Objectives). The FutureTech case study presents several examples of well-planned robot-supported learning designs with well-integrated Learning Objectives (Majgaard et al., 2014). In addition, the recent simplification of the original Common Objectives (as of August 2015) as well as new learning objectives in craft and design (e.g. innovation and entrepreneurship) could possibly ease the introduction of robotics and other “tinkering” tools in schools and the process of identifying learning objectives and legitimizing the technologies in relation to those objectives. However, assessment is still a critical issue. That is, documenting the *outcome* of a learning design and not just its objective.



## ROBOT LITERACY

As we engage in and evaluate robot-mediated teaching and learning, it is important to try to explicate how we as researchers, and conversely how children and teachers as consumers and co-creators of technological practice, *understand* robots. This may refer to two related but separate levels of understanding: our *ontological approach* to robots as mediating artifacts in a given context; and the *skills, knowledge or familiarity* we experience when engaging with technology, also referred to as ‘digital literacy’ or ‘digital competency’ and increasingly required from students, teachers and other professionals. (Bundsgaard et al., 2014; Fraillon et al., 2014).

These two levels of ‘understanding’ are obviously closely linked, since digital literacy is indeed about understanding the interrelationship between technology and practice. When it comes to robots, though, I believe it is relevant to address the two levels separately, particularly because major differences in practitioner’s view and understanding of robots compared to designers, developers and researchers, are often confused with lower digital competency. In my opinion, having another (perhaps less positive) attitude towards or perception of children’s interaction with robots is not equal to lacking the skills needed to analyze and interpret such interaction.

When I discuss ‘robot literacy’ here, it is first and foremost my own approach to the technology as a researcher in robotics that I am discussing and how it has developed throughout the thesis, since my approach to technology naturally shapes my take on robots and the lenses through which I learn from the case studies. However, I have tried to incorporate differing views of robots to discuss how these may in turn reflect different perspectives on interaction and learning. Whereas Fogg’s trichotomy (robots viewed as tools, mediators and social actors) originally referred to particular design strategies for persuasive technologies, these categories may be more applicable as tools to analyze and categorize users’ (in this case, teachers’ and learners’) view, experiences and conceptual understanding of the technologies and the goals and implications associated with its use in a given context. When adding knowledge from HRI and learning to the persuasive categories, we might further define how a robot could be understood as a social actor or simulating medium, but also how it can become a tool or “trigger” within a specific (educational) context.

## SIMULATING MEDIA AND SOCIAL ACTORS

From a PEERs perspective, Fogg’s categories seem related to different cross-fields between persuasive design, HRI and learning. Many e-learning technologies (attempting to make learning easy and motivating) are also understood as *tools* to make knowledge dissemination, acquisition and representation easier, more efficient

or accessible to a larger group, such as MOOCs<sup>10</sup> (Ringtved & Milligan, 2015). The general idea with educational robotics, on the other hand, is not necessarily to make learning *easy*. Rather, key constructionist concepts such as tinkering emphasize play, practical experience and experimentation; “messy” ways of learning (Caprani, 2016; Resnick & Rosenbaum, 2013). This cognitivist/constructionist approach to learning and particularly the concept of ‘micro-worlds’ as a technologically mediated world for students to explore alternatives, test hypotheses, and discover the underlying principles of that particular world (e.g. virtual environments, programming languages or manipulatives) (DiSessa, 2001; Papert, 1980; Rieber, 1996) share similarities with Fogg’s descriptions of *simulating media*. Though simulation in the original persuasive paradigm focuses on the technologically mediated artificial environment or object, adding constructionist perspectives to this concept thus emphasizes the students’ active participation, co-creation, conscious “imitation” and “imagination” rather than a technologically mediated “deception” (Bertel & Hannibal, 2016).

Finally, Socially Assistive Robotics’ emphasis on the *social* interaction between the user and the robot naturally shares similarities with Fogg’s concept of *social actors*, which was the focus of paper III (Bertel & Rasmussen, 2013a, 2013b). However, whereas the original principles of social actors seem somewhat pre-determined (e.g. arguing that technology as an ‘authority’ is by definition persuasive), the intersection between persuasive design and HRI (i.e. persuasive socially assistive robotics) emphasize the complexity and intersubjective meaning-making in the interaction (e.g. explaining why negative outcomes of dominant robot behavior such as psychological reactance is even further enhanced by social agency (M. Roubroeks et al., 2011a)). From this perspective, the purpose and role of the robot is not entirely pre-defined through features and affordances but contextually embedded and socially constructed and negotiated by the people interacting with it and with each other.

Another view on Fogg’s trichotomy could be that of a *spectrum* (of technological approaches and technological development). From this perspective, *mediation* marks a transition. From the robot as merely a ‘tool’ for someone to reach an individual goal; to the robot mediating (congruent or conflicting) goals between users; and eventually to the robot pursuing its own goals as a social actor; a social entity and fully-fledged member of a social realm. This view can also be applied at a meta-analytical level across the case studies, and is reflected e.g. in paper IV (Bertel & Majgaard, 2014), where I discuss the role of the robot, mediation and motivation in the My Pal PARO case. In the one-on-one sessions in the case study, the robot seemed to be framed and understood mostly as a ‘tool’ for specific individual (sensory, cognitive or verbalizing) learning goals. In the triadic interactions between two children and the robot (often facilitated by a teacher), the robot seemed to be attributed a mediating quality; whereas ideas about an independent personality,

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<sup>10</sup> Massive Open Online Course. (“Massive open online course - Wikipedia, the free encyclopedia,” n.d.)

intentionality and sociability was a core element in applications where the robot was considered or at least articulated as an active participant in real social situations. From this perspective, the trichotomy represents not only different abilities, functions, morphologies and roles of robots – it also reflects a process of moving gradually from *automatic* to *autonomous*, from a state of *separation* to *extension* (of the individual using it), to *mediation* (between individuals) and finally to *integration* in the social world of human activity.

From a persuasive learning design perspective, the trichotomy could also mark a transition; from a behavioral to a cognitivist approach to educational robots, further on to a constructionist or constructivist approach, consequently marking a transition from understanding motivation as a cause-and-effect occurrence contingent on feedback from the environment to understanding motivation as immanent, albeit affected by contextual aspects such as experiences of relational symmetry and self-determination. Ultimately, this reflects a transition in the understanding of robots from a technology deterministic perspective to a socio-material one.

## TRIGGERS AND ‘DIAGNOSTIC’ TOOLS

Across all case studies I have seen children who would normally be labeled somewhat impervious to learning become highly engaged in learning activities, e.g. experimenting, categorizing, verbalizing or communicating. In the My Pal PARO project this experience was somewhat unexpected, because of my pre-understanding of what constitutes learning and what minimal communicative abilities are required to take part in learning activities. It is not to say that these children have not previously engaged in such activities, but the robot enabled me as a researcher to see it, and supported the teachers in further facilitating it. Thus, behavior in the My Pal PARO case which I may have otherwise labelled *repetitive*, I saw as inherently *iterative*, *explorative* and *reflective*, an example of experiential learning.

I encountered similar examples in other cases. For instance in the Future-Tech schools, teachers reported that some of the ‘weaker’ students (who they would otherwise have difficulties including in regular learning activities) had a more natural role due to the practical and physical nature of the assignments. These students were participating, focused and motivated. However, according to the teachers’, the effect decreased and the students would ‘fall back’ to their usual interaction patterns (e.g. distracting their classmates), when they were met with “academic” requirements.

One might ask, though, if the real issue lies then with the student? Obviously situations where the specific student participates meaningfully, even actively and engaged can occur, these situations are just currently not recognized as ‘academic’. This indicates that the knowledge and skill required to participate and engage in the kind of complex problem solving opportunities that educational robots might provide are still not recognized as ‘learning’. That is, to some extent only the skills measured

in national and international tests can be considered academic. In my opinion, this is a challenge and a perspective that will and has to change in a largely automated, robotic future. From a PEER perspective, the combination of Fogg's Trigger Model (B. Fogg, 2009), Flow Theory (Nakamura & Csikszentmihalyi, 2014) and the 'Control and Consensus'-correlation (Bertel & Rasmussen, 2013a) might propose a possible explanation to the shifts, these teachers are describing. In Fogg's model, behavior equals motivation + ability + trigger. Thus, when the teachers observe positive behavior change of children with learning disabilities or attention deficits triggered by the robot-supported learning design shifting back, this could be due to increase and subsequent decrease in motivation and ability. Here, the Flow model points to the balance between the perceived challenge and skill level, which mediates the experience (e.g. between "control" and "worry" or between "flow", "arousal" or "anxiety"). From the perspective of the 'Control and Consensus'-correlation (i.e. i.e. experiences of self-determination or perceived congruence in goals (between teacher and student)), this mediation is also socially embedded and could relate to the articulation of the child as a more or less knowledgeable other.

One example in the KRAM NAO Copenhagen project, was a visiting student who was only attending classes temporarily while waiting to be transferred to a different school, and had been assigned to the course as a substitution to regular classroom activities. He was highly intelligent and excelled in the programming course. He solved tasks quickly and searched for new ones online at his own request. He continuously searched for new knowledge and taught himself how to program in Python between two lessons, although it was considered too advanced for the course. The teacher reported that he had previously been skipping school and that it had been somewhat difficult to include him in the classroom activities since he was only visiting, but that this changed with the course and feedback from his parents suggested that he was happier and more excited to go to school. He did not say much and worked mostly alone, and in many cases he would only test his programs in the simulator on the screen, perhaps avoiding the social attention that followed uploading behaviors to the physical robot. After a few times he stopped coming to the course. I did not at first understand why, but I was frustrated about it. He was the good example, a student with challenges in communication and social interaction (perhaps even a diagnosis on the mild end of the spectrum) that just blossomed incredibly with this learning design. *He was the good story.*

What this did, first of all, was revealing my own biases, which triggered a Temple Grandin-inspired reconsideration of my entire approach to PEERs as I explained in the preface, but it also uncovered the importance of being a part of a community of practice (Lave & Wenger, 1991) and the critical role the teacher plays in facilitating such as sense of community. Whereas a PEERs mediate teacher-student or student-student relationships, it does substitute it. It may provide access to a community, but does not in itself maintain this access or transform the underlying structures of the context. Someone has to pick up on these signals, observe and reflect on the

opportunities that they represent for new practices, new rules, roles and relationships, or as Grandin puts it in this precise and clear-cut way, in an email correspondence in response to a request for her thoughts on my project:

*“The robot should be used as a bridge to get the child interested in interacting with people. Building robots is an excellent activity for kids on the spectrum. Robots must never replace people.”* (Grandin, 2015)

Thus, in an ideal scenario, the robot becomes a trigger, a diagnostic tool for us to see the present in a different light. Teachers in the My Pal PARO case reported similar reflections regarding their own practice, describing how the robot had triggered awareness of routines and preconceived notions, e.g. about how rules of turn-taking and sharing might actually obstruct the child’s initiative to engage in social interaction, which was the very goal of the learning design. In this situation, using the robot as a ‘diagnostic’ tool unveiled underlying assumptions and contributed to the re-design of a specific learning design (with and without the robot) as well as the pedagogical principles underpinning this particular practice. Thus, whereas PEER-supported learning designs maybe uncover a *potential* (e.g. excellent programming skills) that might otherwise remain unseen, nurturing this potential and ensuring ongoing motivation is contextual and social, something beyond the technology.

## **DRIVERS OR ACCELERATORS?**

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*Pedagogy is the driver, technology is the accelerator*  
(Michael Fullan, 2011)

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Recognizing that robots themselves do not bring about change, but have the potential to reveal our underlying assumptions about teaching and learning and to trigger reflections, new insights and perspectives that, if put to practice, may support innovation and development, I believe is the key to successful design and implementation of robot-supported teaching and learning. Thus, the challenge of “keeping education relevant” (Johnson et al., 2015) is not only about digitalization, but transformation of traditional education into practice-oriented and innovative teaching (Shear et al., 2011). As argued by Fullan, Bundsgaard and others, in this transition technologies are not drivers but accelerators, amplifying what we are already doing (Bundsgaard et al., 2014; Fullan, 2011). The drivers, on the other hand, are the people (e.g. teachers and practitioners) who introduce the technology and bring it into play with clear visions and goals based on experience, competence and motivation. Thus, from a PEERs perspective, a social robot might trigger or accelerate such processes by sparking curiosity and bringing forward the potential for change as well as its challenges. It is the teacher, however, who drives the change.

This may also explain why PARO robots are sometimes "asleep" in Danish nursing homes, and why NAO robots face the risk of eternal hibernation mode in principals' offices across Danish schools. PARO is often publicly articulated within a discourse of 'replacement', i.e. as an opportunity to release resources, which can be considered both ethically problematic (Sharkey & Sharkey, 2012) and a short respite, since its use often decreases in line with its novelty value (Klein et al., 2013). Although it may detract from the immediate economic rationale for this type of investment, research shows that it is in social situations where staff are present that PARO's potential is fully realized (Kidd, Taggart, & Turkle, 2006) and the same I argue with NAO. Although NAO is not equivalently placed within an economic discourse, both designers and decision makers seem to expect the technology to directly integrate into existing teaching, and in itself improve it. The technology is not, with a few exceptions, part of a larger paradigm shift in education. It is believed to be a driver, but without a transforming pedagogy or learning design, it remains an accelerator.

If the challenge of "keeping education relevant" (Johnson et al., 2015) is about continuously transforming education to suit the future, in my opinion this means *enhancing* and *embracing* the child's spectrum of (dis)abilities. From a Design-Based Research perspective, this can be done through participatory learning environments that "encourage explanation and discovery, nurture reflection, and support students in the carrying out of practices that embody personally meaningful and practically functional representations" (S. A. Barab, Hay, Barnett, & Squire, 2001: 48).

Enhancing and embracing the spectrum of abilities is a fundamental yet highly complex task, relevant to everyone in the educational system all the way from policy- and decision making to the task of putting these policies into professional practice. It suggests evolving from a teacher curriculum where learning is considered only the acquisition of facts or skills, to a learner curriculum (Lave & Wenger, 1991) where learning is conceived as a social process, involving the appropriation and construction of meaning through participation in a trajectory of experience (S. A. Barab et al., 2001: 48). From a PEERs perspective, this ultimately requires a shift in our perception of the *targets* of persuasive educational interventions; from the *learners* to the *contexts of learning* and of *change*; from something that happens solely in the mind of the learner, to something that might happen if we recognize that the world does, in fact, need all kinds of minds.

# OUTRO

## POSSIBILITIES AND CHALLENGES IN INDUSTRIAL RESEARCH

The role as an industrial researcher has an inherent duality - as a researcher my main academic aim is to develop and disseminate new knowledge, however this knowledge should also to some extent be applied commercially. The commercial aspect emphasizes the applicability of research to practice which is very much in line with my academic design-based research goals. However, it could also challenge my ‘objectivity’ towards the applied technologies, since any choice of technological artifact implies a preconception, an (unspoken) hypothesis that carries biases, which of course may be further enhanced by commercial interests in the project. Even though revenue related to distribution is minor, the fact that DTI may undertake distribution of certain products for some time (which have been the case with both PARO and NAO) means that I as an industrial researcher may get both professionally and personally involved with those products.

When it comes to conducting research, the duality in my role as both a researcher and industrial partner in research projects naturally entails some weaknesses. In addition to being tied to the availability of specific technologies, I have also had an operational role, providing technical support myself, which naturally reduced the level of attention to other aspects of the interaction in these specific situations. Conversely though, the obligation to the technology motivated me to notice the subtle differences in the robot-supported learning designs and the views on motivation, learning and interaction that they represent. Had I not a particular interest in the technology “working”, I might have quickly concluded that it did not, which would have prevented me from seeing the potential in ‘flawed’ technologies.

To separate and support synergy between industrial and research interests in this project, it has been essential for me to focus on the Danish Technological Institute’s identity as a non-profit approved technological service provider (‘Godkendt Teknologisk Serviceinstitut’ in Danish) that as such do not have products to sell or a specific commercial interest in certain products compared to others. Rather, DTI is supposed to help companies introduce products to the market in an efficient manner and support decision-makers and consumers to prioritize, implement and apply products in practice with attention to user needs and contextual factors affecting implementation. This has just as much to do with identifying stakeholders’ values and needs, applying user-centered methods and designing innovative interventions, as it has to do with the specific technologies applied. Hence, the commercial interest in the project was never to sell more PARO’s or NAO’s, but to investigate methods and processes for implementing (any) social robot in complex contexts, which can then be made available as commercial products for professional development.

Hence, the fact that already purchased PARO's and NAO's in Danish schools, nurseries, hospitals and nursing homes may remain unused is an important point in my project. Just as 'use' does not necessarily implies 'useful', less use does not necessarily implies 'useless'. The fact that our partner in the FutureTech case, Insero, who acquired three NAO robots as part of the project and made them available to all schools in the area, reports that they are still used a lot – but primarily by schools and teachers who already participated in the project, confirms that guided innovation processes through which development of both supporting materials and teachers' competencies for the design of robot-supported learning is prioritized, is just as (and perhaps more) important than the specific features and affordances of the technology, which is relevant for both producers and distributors of social robots and similar technologies as well as for decision-makers and practitioners.

## **FUTURE WORK**

From a persuasive design perspective, the Design-Based Research approach in the project can be considered an attempt to align goals between research and practice and balance the inherently asymmetrical relationship between researcher and subject. However, it should be noted that the case studies present a somewhat narrow take on the 'subject', represented mostly by teachers and lacking a consistent and direct involvement of the students in the 'co-ideation' phase, whose ideas and views should ideally be included in design processes as well.

Particularly in the My Pal PARO project I lacked the tools and expertise to communicate with the children on their terms, hence I somewhat find myself in the category of HRI researchers in autism education that I myself criticize for failing to include the interests and views, hopes and dreams that the interventions I design are actually supposed to address (Hansbøl, 2016). I would argue, though, that the teachers to a great extent actually did take a participatory approach to the involvement of the students, encouraging and following their suggestions in and initiation and termination of interaction. In future research, though, it will important to further explore possibilities of directly including the views and interests of this particular user group (and many others with similar communication patterns) e.g. through play and alternative communication and design methods, which is also addressed within the participatory design field (e.g. Slegers, Duysburgh, & Hendriks, 2014).

In the NAO cases, the students could also have been more directly involved, e.g. participating in the learning design workshop (and not just the technical course) or actually developing learning designs for fellow students. This was somewhat the case in the KRAM NAO case, however the framing was mainly symbolic and the supposed recipients of these designs obviously theoretical. To support this approach we could have defined a real target audience (e.g. a lower grade class or a class at neighboring school) and invited them to participate in the closing events and presentations or evaluate the student-developed designs. This way, the learning



designs would also have utilized the concept of ‘learning by teaching’ advocated in chapter 1. Finally, as we argue in paper V (Bertel & Hannibal, 2016) the children’s first encounter with robots reveal information about students’ interests and motivation (i.e. through framing/narration, imitation and rehearsal of social concepts), which emphasizes the importance of including this aspect in initial explorative phase of future design-based research studies on PEERs.

As I emphasize the persuasive potential of robots in their ‘frailty’, it would be interesting to dig deeper into these observations. First of all to understand whether this is contextual or whether it applies to other contexts as well, and if so to explore the possibility of including it as an actual design feature in Human-Robot Interaction. In this thesis, my focus has mainly been on *what* happens when children encounter robots in this way, rather than *why* this is happening. To get a deeper understanding of the underlying mechanisms of this concept it would be necessary to reexamine the data in detail with a magnifying glass, to grasp the subtle shifts in the interaction e.g. by applying ethnomethodological and embodied interaction analysis approaches as suggested by (Davidsen & Christiansen, 2014; Davidsen & Vanderlinde, 2013) and applying micro-study approaches to be able to predict and design for them.

In terms of methodology it could be interesting to include quantitative methods as part of the research design in future PEER-studies e.g. as suggested in (Marianne Lykke et al., 2015) and to explore creative and innovative approaches to qualitative data collection and user-involvement, e.g. by collaborating with teachers and DBR-partners more directly in the interpretation of data (as suggested by (Davidsen & Vanderlinde, 2014) or by exploring methods from other intersections between robotics and the humanities, such as Robot Aesthetics (Christoffersen, Nielsen, Jochum, & Tan, 2015; Jochum, Borggreen, & Murphey, 2016; Vlachos, Jochum, & Schärfe, 2016).

From an industrial perspective, the next step is to integrate the findings of the thesis into practice and policies in partnership with designers and developers of educational robotics (an industrial robots applicable to educational environments) as well as primary and secondary educational institutions, teacher education institutions, universities, key organizations and networks of schools who are already working with or plan to work with robots for learning. In the first phase we are forming collaborations to apply for national funding to further investigate and document the suggested methods and PEER-supported learning designs across educational contexts and in the following phases we aim to extend our collaboration to include European and international partners as well.

# BIBLIOGRAPHY

- Akker, J. V. den, Gravemeijer, K., McKenney, S., & Nieveen, N. (2006). *Educational Design Research*. Routledge.
- Aldebaran Community. (2015, February 11). About the ASK NAO initiative. Retrieved March 31, 2016, from <https://community.aldebaran.com/en/forum/about-ask-nao-initiative-2457>
- Aldebaran Robotics. (2016). Discover Nao, the little humanoid robot from Aldebaran | Aldebaran. Retrieved March 31, 2016, from <https://www.aldebaran.com/en/cool-robots/nao>
- Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education*, 6(1), 63–71.
- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)* (Fifth Edition). American Psychiatric Association.
- Amiel, T., & Reeves, T. C. (2008). Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda. *Educational Technology & Society*, 11(4), 29–40.
- Anderson, T., & Shattuck, J. (2012). Design-Based Research A Decade of Progress in Education Research? *Educational Researcher*, 41(1), 16–25.
- Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191.
- Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall, Inc.
- Barab, S. A., Hay, K. E., Barnett, M., & Squire, K. (2001). Constructing virtual worlds: Tracing the historical development of learner practices. *Cognition and Instruction*, 19(1), 47–94.
- Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences*, 13(1), 1–14.
- Bartneck, C., Kanda, T., Mubin, O., & Al Mahmud, A. (2009). Does the design of a robot influence its animacy and perceived intelligence? *International Journal of Social Robotics*, 1(2), 195–204.
- Bartneck, C., Nomura, T., Kanda, T., Suzuki, T., & Kenssuke, K. (2005). A cross-cultural study on attitudes towards robots. In *HCI International*.

- Basten, F., Ham, J., Midden, C., Gamberini, L., & Spagnolli, A. (2015). Does Trigger Location Matter? The Influence of Localization and Motivation on the Persuasiveness of Mobile Purchase Recommendations. In T. MacTavish & S. Basapur (Eds.), *Persuasive Technology* (pp. 121–132). Springer International Publishing.
- Baxter, P., Ashurst, E., Kennedy, J., Senft, E., Lemaignan, S., & Belpaeme, T. (2015). The Wider Supportive Role of Social Robots in the Classroom for Teachers. In *Proceedings of the 1st International Workshop on Educational Robots (WONDER)*. Paris.
- Baxter, P., Belpaeme, T., Canamero, L., Cosi, P., Demiris, Y., Enescu, V., ... others. (2011). Long-term human-robot interaction with young users. In *IEEE/ACM Human-Robot Interaction 2011 Conference (Robots with Children Workshop)*.
- Baxter, P., Wood, R., & Belpaeme, T. (2012). A touchscreen-based “Sandtray” to facilitate, mediate and contextualise human-robot social interaction. In *Human-Robot Interaction (HRI), 2012 7th ACM/IEEE International Conference on* (pp. 105–106). IEEE.
- Belpaeme, T., Baxter, P. E., Read, R., Wood, R., Cuayáhuitl, H., Kiefer, B., ... Humbert, R. (2012). Multimodal Child-Robot Interaction: Building Social Bonds. *Journal of Human-Robot Interaction*, 1(2), 33–53.
- Bers, M., Ponte, I., Juelich, K., Viera, A., & Schenker, J. (2002). Teachers as designers: Integrating robotics in early childhood education. *Information Technology in Childhood Education*, 1, 123–145.
- Bertel, L. B. (2010). The Use of Rewards in Persuasive Design. In *Persuasive 2010 Proceedings of Poster Papers for the Fifth International Conference on Persuasive Technology*. Copenhagen: Oulu University Press.
- Bertel, L. B. (2011, August 1). *PEER - Persuasive Educational & Entertainment Robotics* (Master’s thesis). Aalborg University, Aalborg, Denmark.
- Bertel, L. B. (2013). Persuasive Educational and Entertainment Robotics (PEERs). Presented at the 1st AAU Workshop on Human-Centered Robotics, Aalborg University Press.
- Bertel, L. B. (2014). *KRAM NAO København* (Projektrapport). København: Teknologisk Institut.
- Bertel, L. B., & Hannibal, G. (2016). The NAO robot as a Persuasive Educational and Entertainment Robot (PEER) – a case study on children’s articulation, categorization and interaction with a social robot for learning. *Tidsskriftet Læring og Medier (LOM)*, 8(14).

- Bertel, L. B., & Majgaard, G. (2014). Persuasive Educational & Entertainment Robotics (PEERs) - Aligning Asymmetric Interactions in Education. Presented at the HRI 2014 Workshop on Humans and Robots in Asymmetric Interactions, Bielefeld, Germany.
- Bertel, L. B., & Rasmussen, D. M. (2013a). On Being a Peer: What Persuasive Technology for Teaching Can Gain from Social Robotics in Education. *International Journal of Conceptual Structures and Smart Applications*, 1(2), 58–68.
- Bertel, L. B., & Rasmussen, D. M. (2013b). PEERs at Play: A Case Study on Persuasive Educational and Entertainment Robotics in Autism Education. In *Proceedings of the International Workshop on EUROPLoT Persuasive Technology for Learning, Education, and Teaching (IWEPLET 2013)* (pp. 161–168).
- Bertel, L. B., Rasmussen, D. M., & Christiansen, E. (2013). Robots for Real: Developing a Participatory Design Framework for Implementing Educational Robots in Real-World Learning Environments. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013* (pp. 437–444). Springer Berlin.
- Bertel, L. B., Rasmussen, D. M., & Majgaard, G. (2015). Design-Based Research in Child-Robot Interaction - Bridging the Gap between the intended and the implemented. In *Proceedings of the 1st Workshop on Evaluating Child Robot Interaction*. Paris, France.
- Biggs, J. B. (2011). *Teaching for quality learning at university: What the student does*. McGraw-Hill Education (UK).
- Blikstein, P. (2013). Digital fabrication and “making” in education: The democratization of invention. *FabLabs: Of Machines, Makers and Inventors*, 1–21.
- Bloom, B. S. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*. D. McKay.
- Breazeal, C. (2003). Toward sociable robots. *Robotics and Autonomous Systems*, 42(3–4), 167–175.
- Breazeal, C. (2009). Role of expressive behaviour for robots that learn from people. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 364(1535), 3527–3538.
- Breazeal, C., & Scassellati, B. (1999). How to build robots that make friends and influence people. In *Intelligent Robots and Systems, 1999. IROS'99. Proceedings. 1999 IEEE/RSJ International Conference on* (Vol. 2, pp. 858–863). IEEE.
- Brooks, R. (1986). A robust layered control system for a mobile robot. *IEEE Journal on Robotics and Automation*, 2(1), 14–23.

- Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. *Journal of the Learning Sciences*, 2(2), 141–178.
- Bundsgaard, J., Pettersson, M., & Puck, M. R. (2014). *Digitale kompetencer*. Aarhus Universitetsforlag.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, CO: BSCS*, 5, 88–98.
- Cameron, J. (2006). *Rewards and Intrinsic Motivation: Resolving the Controversy*. IAP.
- Caprani, O. (2016). Mangfoldige læringsaktiviteter-ét robotbyggesæt. *Tidsskriftet Læring Og Medier (LOM)*, 8(14).
- Caprani, O., & Thestrup, K. (2010). Det eksperimenterende fællesskab -Børn og voksnes leg med medier og teknologi. *Tidsskriftet Læring Og Medier (LOM)*, 3(5).
- Castellano, G., Aylett, R., Dautenhahn, K., Paiva, A., McOwan, P. W., & Ho, S. (2008). Long-term affect sensitive and socially interactive companions. In *Proceedings of the 4th International Workshop on Human-Computer Conversation*.
- Castellano, G., Leite, I., Pereira, A., Martinho, C., Paiva, A., & McOwan, P. W. (2010). Affect recognition for interactive companions: challenges and design in real world scenarios. *Journal on Multimodal User Interfaces*, 3(1-2), 89–98.
- Castellano, G., Leite, I., Pereira, A., Martinho, C., Paiva, A., & McOwan, P. W. (2012). Detecting Engagement in HRI: An Exploration of Social and Task-Based Context. In *Privacy, Security, Risk and Trust (PASSAT), 2012 International Conference on and 2012 International Confernece on Social Computing (SocialCom)* (pp. 421–428).
- Chaiklin, S. (2003). The zone of proximal development in Vygotsky's analysis of learning and instruction. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller, *Vygotsky's educational theory in cultural context* (Vol. 1, pp. 39–64). Cambridge University Press.
- Chandra, S., Alves-Oliveira, P., Lemaignan, S., Sequeira, P., Paiva, A., & Dillenbourg, P. (2015). Can a child feel responsible for another in the presence of a robot in a collaborative learning activity? In *Robot and Human Interactive Communication (RO-MAN), 2015 24th IEEE International Symposium on* (pp. 167–172). IEEE.
- Chao, C., & Thomaz, A. L. (2010). Turn Taking for Human-Robot Interaction. In *AAAI fall symposium: dialog with robots*.

- Christoffersen, A., Nielsen, S. G., Jochum, E., & Tan, Z. H. (2015). Robot Futures: Using Theatre to Influence Acceptance of Care Robots. Presented at the New Friends, Almere, Holland.
- Choi, J.-H., Lee, J.-Y., & Han, J.-H. (2008). Comparison of cultural acceptability for educational robots between Europe and Korea. *Journal of Information Processing Systems*, 4(3), 97–102.
- Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher*, 32(1), 9–13.
- Collins, A. (1992). Toward a Design Science of Education. In E. Scanlon & T. O'Shea (Eds.), *New Directions in Educational Technology* (pp. 15–22). Springer Berlin Heidelberg.
- Corrigan, L. J., Peters, C., Castellano, G., Papadopoulos, F., Jones, A., Bhargava, S., ... Aylett, R. (2013). Social-task engagement: striking a balance between the robot and the task. In *Embodied Commun. Goals Intentions Workshop ICSR* (Vol. 13, pp. 1–7).
- Csikszentmihalyi, M. (1975). *Beyond Boredom and Anxiety*. Jossey-Bass Publishers.
- Csikszentmihalyi, M. (1997). *Finding flow: The psychology of engagement with everyday life*. Basic Books.
- Danish Technological Institute. (2014). *PRACE - Programming by Demonstration Using 6D Marker Tracking* (video). Retrieved from <https://www.youtube.com/watch?v=fIVrMrwng-Y>
- Dautenhahn, K. (2007a). Methodology and themes of human-robot interaction: a growing research field. *International Journal of Advanced Robotic Systems*.
- Dautenhahn, K. (2007b). Socially intelligent robots: dimensions of human–robot interaction. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 362(1480), 679–704.
- Dautenhahn, K., Woods, S., Kaouri, C., Walters, M. L., Koay, K. L., & Werry, I. (2005). What is a robot companion-friend, assistant or butler? In *Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on* (pp. 1192–1197). IEEE.
- Davidson, J., & Christiansen, E. (2014). Mind the hand: A study on children's embodied and multimodal collaborative learning around touchscreens. *Designs for Learning*, 7(1), 34–53.
- Davidson, J., & Vanderlinde, R. (2013). Micro Ethnographic Research as a Method for Informing Educational Technology Design in Practice. In *American Educational Research Association. Annual Meeting Program*.

- Davidsen, J., & Vanderlinde, R. (2014). Researchers and teachers learning together and from each other using video-based multimodal analysis. *British Journal of Educational Technology*, 45(3), 451–460.
- Davis, J. (2008). Towards participatory design of ambient persuasive technology. *Proceedings of Persuasive 2008 Workshop*.
- Davis, J. (2009). Design methods for ethical persuasive computing. In *Proceedings of the 4th International Conference on Persuasive Technology* (p. 6). ACM.
- Dede, C. (2004). If Design-Based Research Is the Answer, What Is the Question? A Commentary on Collins, Joseph, and Bielaczyc; diSessa and Cobb; And Fishman, Marx, Blumenthal, Krajcik, and Soloway in the JLS Special Issue on Design-Based Research. *The Journal of the Learning Sciences*, 13(1), 105–114.
- Dewey, J. (1910). *How We Think*. D.C. Heath & Company.
- Dewey, J. (1938). *Education and experience*. New York: Macmillan.
- DiSessa, A. A. (2001). *Changing minds: Computers, learning, and literacy*. MIT Press.
- Dougherty, E. G., & Scharfe, H. (2011). Initial Formation of Trust: Designing an Interaction with Geminoid-DK to Promote a Positive Attitude for Cooperation. In B. Mutlu, C. Bartneck, J. Ham, V. Evers, & T. Kanda (Eds.), *Social Robotics* (pp. 95–103). Springer Berlin Heidelberg.
- Dudley-Marling, C. (2004). The Social Construction of Learning Disabilities. *Journal of Learning Disabilities*, 37(6), 482–489.
- Engineer the Future. (2015). Massiv ingeniørmangel | Engineer the future.dk. Retrieved March 25, 2016, from <http://engineerthefuture.dk/ingeniormangel>
- European Commission. (2013, 2015). H2020-SEAC-2014-2015. Retrieved March 25, 2016, from <https://ec.europa.eu/>
- Evaluating Child Robot Interaction. (2016). Retrieved March 26, 2016, from <https://evaluatingchildrobotinteraction.wordpress.com/>
- Fagin, B. S., & Merkle, L. (2002). Quantitative analysis of the effects of robots on introductory Computer Science education. *Journal on Educational Resources in Computing (JERIC)*, 2(4), 2.
- Feil-Seifer, D., & Matarić, M. J. (2005). Defining socially assistive robotics. In *Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on* (pp. 465–468). IEEE.
- Feil-Seifer, D., & Matarić, M. J. (2009). Toward socially assistive robotics for augmenting interventions for children with autism spectrum disorders. In *Experimental robotics* (pp. 201–210). Springer.

- Feil-Seifer, D., & Matarić, M. J. (2011). Socially assistive robotics. *Robotics & Automation Magazine, IEEE*, 18(1), 24–31.
- Fischer, K., Yang, S., Mok, B., Maheshwari, R., Sirkin, D., & Ju, W. (2015). Initiating Interactions and Negotiating Approach: A Robotic Trash Can in the Field. In *2015 AAAI Spring Symposium Series*.
- Fogg, B. (2009). A Behavior Model for Persuasive Design. In *Proceedings of the 4th International Conference on Persuasive Technology* (pp. 40:1–40:7). New York, NY, USA: ACM.
- Fogg, B. J. (2003). *Persuasive Technology: Using Computers to Change what We Think and Do*. Morgan Kaufmann.
- Fogg, B. J. (2016). BJ Fogg's Behavior Model. Retrieved March 27, 2016, from <http://www.behaviormodel.org/>
- Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and Autonomous Systems*, 42(3–4), 143–166.
- Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). Preparing for life in a digital age. *The IEA International Computer and Information Literacy Study International Report*. Cham: Springer.
- Frank, L. (2013, June 10). Robottens indtog i folkeskolen: Nu kommer Nao til de jyske klasser - Folkeskolen.dk. *Folkeskolen.dk*. Retrieved from <https://www.folkeskolen.dk/530862/robottens-indtog-i-folkeskolen-nu-kommer-nao-til-de-jyske-klasser>
- Fullan, M. (2011). *Choosing the wrong drivers for whole system reform*. Centre for Strategic Education East Melbourne.
- Fullan, M., & Langworthy, M. (2014). How New Pedagogies Find Deep Learning.— January 2014.
- Garcia, M. A., & Patterson-McNeill, H. (2002). Learn how to develop software using the toy Lego Mindstorms. In *Frontiers in Education, 2002. FIE 2002. 32nd Annual* (Vol. 3, p. S4D–7). IEEE.
- Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural Probes. *Interactions*, 6(1), 21–29.
- Ghosh, M., & Tanaka, F. (2011). The impact of different competence levels of care-receiving robot on children. In *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on* (pp. 2409–2415). IEEE.
- Gram-Hansen, S. B. (2016). The EDIE method - towards an approach to collaboration-based persuasive design. In *Proceedings of the 11th International Conference on Persuasive Technology*. Salzburg: in press.



- Gram-Hansen, S. B., & Gram-Hansen, L. B. (2013). On the role of Ethics in Persuasive Design. *Ethicomp 2013*.
- Gram-Hansen, S. B., & Ryberg, T. (2013). Persuasion, Learning and Context Adaptation. *International Journal of Conceptual Structures and Smart Applications (IJCSSA)*, 1(2), 28–37.
- Gram-Hansen, S. B., & Ryberg, T. (2015). Attention–Influencing Communities of Practice with Persuasive Learning Designs. In *Persuasive Technology* (pp. 184–195). Springer.
- Gram-Hansen, S. B., & Ryberg, T. (2016). From Participatory Design and Ontological Ethics, Towards an Approach to Constructive Ethics. *SIGCAS Comput. Soc.*, 45(3), 147–153.
- Grandin, T. (2010). Temple Grandin | Speaker | TED.com. Retrieved March 29, 2016, from [https://www.ted.com/speakers/temple\\_grandin](https://www.ted.com/speakers/temple_grandin)
- Grandin, T. (2015, July 7). Response from Temple Grandin. (email)
- Green, A., Huttenrauch, H., & Eklundh, K. S. (2004). Applying the Wizard-of-Oz framework to cooperative service discovery and configuration. In *Robot and Human Interactive Communication, 2004. ROMAN 2004. 13th IEEE International Workshop on* (pp. 575–580). IEEE.
- Greve Kommune. (2015, March 25). Greve vinder digitaliseringspris med robot. Retrieved March 31, 2016, from <http://www.greve.dk/Om%20kommunen/Nyheder/2015/3/Digitaliseringspris%202015.aspx>
- Grzega, J., & Schöner, M. (2008). The didactic model LdL (Lernen durch Lehren) as a way of preparing students for communication in a knowledge society. *Journal of Education for Teaching*, 34(3), 167–175.
- Ham, J., Bokhorst, R., Cuijpers, R., van der Pol, D., & Cabibihan, J.-J. (2011). Making robots persuasive: the influence of combining persuasive strategies (gazing and gestures) by a storytelling robot on its persuasive power. In *Social robotics* (pp. 71–83). Springer.
- Ham, J., & Midden, C. (2009). A Robot That Says Bad!: Using Negative and Positive Social Feedback from a Robotic Agent to Save Energy. In *Proceedings of the 4th ACM/IEEE International Conference on Human Robot Interaction* (pp. 265–266). New York, NY, USA: ACM.
- Ham, J., & Midden, C. J. (2014). A persuasive robot to stimulate energy conservation: the influence of positive and negative social feedback and task similarity on energy-consumption behavior. *International Journal of Social Robotics*, 6(2), 163–171.

- Ham, J., & Spahn, A. (2015). Shall I Show You Some Other Shirts Too? The Psychology and Ethics of Persuasive Robots. In R. Trappl (Ed.), *A Construction Manual for Robots' Ethical Systems* (pp. 63–81). Springer International Publishing.
- Hammer, S., Lugin, B., Bogomolov, S., Janowski, K., & André, E. (2016). Investigating Politeness Strategies and Their Persuasiveness for a Robotic Elderly Assistant. In *Persuasive Technology* (pp. 315–326). Springer.
- Hamner, E., Lauwers, T., Bernstein, D., Nourbakhsh, I. R., & DiSalvo, C. F. (2008). Robot Diaries: Broadening Participation in the Computer Science Pipeline through Social Technical Exploration. In *AAAI Spring Symposium: Using AI to Motivate Greater Participation in Computer Science* (pp. 38–43).
- Han, J. (2010). Robot-Aided Learning and r-Learning Services. In D. Chugo (Ed.), *Human-Robot Interaction*. InTech.
- Han, J., Hyun, E., Kim, M., Cho, H., Kanda, T., & Nomura, T. (2009). The Cross-cultural Acceptance of Tutoring Robots with Augmented Reality Services. *JDCTA*, 3(2), 95–102.
- Han, J., & Kim, D. (2009). r-Learning services for elementary school students with a teaching assistant robot. In *Human-Robot Interaction (HRI), 2009 4th ACM/IEEE International Conference on* (pp. 255–256). IEEE.
- Hannibal, G. (2014). “Dynamic”Categorization and Rationalized Ascription: A Study on NAO. *Sociable Robots and the Future of Social Relations: Proceedings of Robo-Philosophy 2014*, 273, 343.
- Hansbøl, M. (2016). Robot technologies, autism and designs for learning. *Tidsskriftet Læring Og Medier (LOM)*, 8(14).
- Hansen, J. J. (2012). *Dansk som undervisningsfag - perspektiver på didaktik og design* (Vol. 2012). Dansklærerforeningens Forlag.
- Hansen, J. J. (2016). Robotdidaktik. Læringsrobotter som indhold i undervisningen. *Tidsskriftet Læring og Medier (LOM)*, 8(14).
- Hermansen, M. (1996). *Læringens univers* (Vol. 5). Klim.
- Heron, J. (1996). *Co-Operative Inquiry: Research Into the Human Condition*. SAGE.
- Hjorth, M., Iversen, O. S., Smith, R. C., Christensen, K. S., & Blikstein, P. (2015). Digital Technology and Design Processes: Report on a FabLab@ School survey among Danish youth.
- Hood, D., Lemaignan, S., & Dillenbourg, P. (2015). When children teach a robot to write: An autonomous teachable humanoid which uses simulated handwriting. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction* (pp. 83–90). ACM.

- Insero Science Academy. (2013, October 23). Så er projekt Fremtek skudt i gang. Retrieved March 31, 2016, from <http://academy.insero.dk/2013/10/sa-er-fremtek-projektet-skudt-i-gang/>
- Ioannou, A., Andreou, E., & Christofi, M. (2015). Pre-schoolers' Interest and Caring Behaviour Around a Humanoid Robot. *TechTrends*, 59(2), 23–26.
- Jacq, A. D., Garcia, F., Dillenbourg, P., Paiva, A., & others. (2016). Building successful long child-robot interactions in a learning context. In *Proceedings of the 2016 ACM/IEEE Human-Robot Interaction Conference*.
- Jochum, E., Borggreen, G., & Murphey, T. D. (2016). INTERACT: Applying Theory and Methods from the Visual and Performing Arts to Robots. In *Workshop on Culture Aware Robotics*. Bielefeld, Germany.
- Johnson, L., Adams Becker, S., & Hall, C. (2015). *2015 NMC Technology Outlook for Scandinavian Schools: A Horizon Project Regional Report*. Austin, Texas.
- Jones, A., Küster, D., Basedow, C. A., Alves-Oliveira, P., Serholt, S., Hastie, H., ... Castellano, G. (2015). Empathic Robotic Tutors for Personalised Learning: A Multidisciplinary Approach. In A. Tapus, E. André, J.-C. Martin, F. Ferland, & M. Ammi (Eds.), *Social Robotics* (pp. 285–295). Springer International Publishing.
- Journal of Human-Robot Interaction. (2016). Retrieved March 26, 2016, from <http://humanrobotinteraction.org/journal/index.php/HRI>
- Kahn, P. H., Freier, N. G., Friedman, B., Severson, R. L., & Feldman, E. N. (2004). Social and moral relationships with robotic others? In *13th IEEE International Workshop on Robot and Human Interactive Communication, 2004. ROMAN 2004* (pp. 545–550).
- Kahn, P. H., Jr., Reichert, A. L., Gary, H. E., Kanda, T., Ishiguro, H., Shen, S., ... Gill, B. (2011). The New Ontological Category Hypothesis in Human-robot Interaction. In *Proceedings of the 6th International Conference on Human-robot Interaction* (pp. 159–160). New York, NY, USA: ACM.
- Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. *Human-Computer Interaction*, 19(1), 61–84.
- Kaptein, M., Eckles, D., & Davis, J. (2011). Envisioning persuasion profiles: challenges for public policy and ethical practice. *Interactions*, 18(5), 66–69.
- Karna-Lin, E., Pihlainen-Bednarik, K., Sutinen, E., & Virnes, M. (2006). Can Robots Teach? Preliminary Results on Educational Robotics in Special Education. In *Sixth International Conference on Advanced Learning Technologies, 2006* (pp. 319–321).

- Kennedy, J., Baxter, P., & Belpaeme, T. (2015). The robot who tried too hard: social behaviour of a robot tutor can negatively affect child learning. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction* (pp. 67–74). ACM.
- Kidd, C. D., Taggart, W., & Turkle, S. (2006). A sociable robot to encourage social interaction among the elderly. In *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on* (pp. 3972–3976). IEEE.
- Kim, E. S., Paul, R., Shic, F., & Scassellati, B. (2012). Bridging the Research Gap: Making HRI Useful to Individuals with Autism. *Journal of Human-Robot Interaction*, 1(1).
- Kim, K. J., Park, E., & Sundar, S. S. (2013). Caregiving role in human–robot interaction: A study of the mediating effects of perceived benefit and social presence. *Computers in Human Behavior*, 29(4), 1799–1806.
- Klein, B., Gaedt, L., & Cook, G. (2013). Emotional robots: Principles and experiences with Paro in Denmark, Germany, and the UK. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry*, 26(2), 89–99.
- Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.
- Kolb, D. A., Boyatzis, R. E., Mainemelis, C., & others. (2001). Experiential learning theory: Previous research and new directions. *Perspectives on Thinking, Learning, and Cognitive Styles*, 1, 227–247.
- Kory Westlund, J. (2015). Telling Stories with Green the DragonBot: A Showcase of Children’s Interactions Over Two Months. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts* (pp. 263–263). New York, NY, USA: ACM.
- Kory Westlund, J., Gordon, G., Spaulding, S., Lee, J. J., Plummer, L., Martinez, M., ... Breazeal, C. (2016). Lessons From Teachers on Performing HRI Studies with Young Children in Schools. In *The Eleventh ACM/IEEE International Conference on Human Robot Interaction* (pp. 383–390). Piscataway, NJ, USA: IEEE Press.
- Kose-Bagci, H., Dautenhahn, K., & Nehaniv, C. L. (2008). Emergent dynamics of turn-taking interaction in drumming games with a humanoid robot. In *Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on* (pp. 346–353). IEEE.
- Lammer, L., Huber, A., Weiss, A., & Vincze, M. (2014). Mutual care: How older adults react when they should help their care robot. In *AISB2014: Proceedings of the 3rd international symposium on new frontiers in human–robot interaction* (pp. 1–4).

- Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.
- Lawhead, P. B., Duncan, M. E., Bland, C. G., Goldweber, M., Schep, M., Barnes, D. J., & Hollingsworth, R. G. (2002). A road map for teaching introductory programming using LEGO\copyright mindstorms robots. In *ACM SIGCSE Bulletin* (Vol. 35, pp. 191–201). ACM.
- Lee, E., Lee, Y., Kye, B., & Ko, B. (2008). Elementary and middle school teachers', students' and parents' perception of robot-aided education in Korea. In *World conference on educational multimedia, hypermedia and telecommunications, Vienna* (pp. 175–183).
- Lee, K. M., Jung, Y., Kim, J., & Kim, S. R. (2006). Are physically embodied social agents better than disembodied social agents?: The effects of physical embodiment, tactile interaction, and people's loneliness in human–robot interaction. *International Journal of Human-Computer Studies*, 64(10), 962–973.
- LEGO Mindstorms. (2016). LEGO® MINDSTORMS®. Retrieved March 28, 2016, from <http://www.lego.com/en-us/mindstorms/>
- Leite, I., Castellano, G., Pereira, A., Martinho, C., & Paiva, A. (2012). Long-Term Interactions with Empathic Robots: Evaluating Perceived Support in Children. In S. S. Ge, O. Khatib, J.-J. Cabibihan, R. Simmons, & M.-A. Williams (Eds.), *Social Robotics* (pp. 298–307). Springer Berlin Heidelberg.
- Leite, I., Martinho, C., Pereira, A., & Paiva, A. (2008). iCat: An Affective Game Buddy Based on Anticipatory Mechanisms. In *Proceedings of the 7th International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 3* (pp. 1229–1232). Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems.
- Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues*, 2, 4, 34–46.
- Lin, Y.-C., Liu, T.-C., Chang, M., & Yeh, S.-P. (2009). Exploring children's perceptions of the robots. In *Learning by Playing. Game-based Education System Design and Development* (pp. 512–517). Springer.
- Liu, E. Z.-F. (2010). Early adolescents' perceptions of educational robots and learning of robotics. *British Journal of Educational Technology*, 41(3), E44–E47.
- Lockton, D., Harrison, D., & Stanton, N. A. (2010). The Design with Intent Method: A design tool for influencing user behaviour. *Applied Ergonomics*, 41(3), 382–392.
- Løgstrup, K. E. (1956). Den etiske fordring (The ethical demand). *Copenhagen, Denmark: Gyldendalske Boghandel Nordisk Forlag*.

- Lu, S., Ham, J., & Midden, C. (2016). Red Radiators Versus Red Tulips: The Influence of Context on the Interpretation and Effectiveness of Color-Based Ambient Persuasive Technology. In *Persuasive Technology* (pp. 303–314). Springer.
- Lykke, M., Coto, M., Jantzen, C., Mora, S., & Vandel, N. (2015). Motivating Students Through Positive Learning Experiences: A Comparison of Three Learning Designs for Computer Programming Courses. *Journal of Problem Based Learning in Higher Education*, 3(2).
- Lykke, M., Coto, M., Mora, S., Vandel, N., & Jantzen, C. (2014). Motivating programming students by problem based learning and LEGO robots. In *2014 IEEE Global Engineering Education Conference (EDUCON)* (pp. 544–555).
- Majgaard, G. (2011). *Læreprocesser og robotsystemer: Design af læremidler og læreprocesser med robotter som medier og børn som med-designere* (PhD Dissertation). University of Southern Denmark.
- Majgaard, G., & Bertel, L. (2014). Initial Phases of Design-based Research into the Educational Potentials of NAO-robots. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction* (pp. 238–239). Bielefeld, Germany: ACM.
- Majgaard, G., Hansen, J. J., Bertel, L., & Pagh, A. (2014). Fra digitalt design til fysisk udtryk – anvendelse af 3-d-printere og NAO-robotter i folkeskolen. *MONA - Matematik- og Naturfagsdidaktik*, 0(4).
- Majgaard, G., Misfeldt, M., & Nielsen, J. (2010). Robot technology and numbers in the classroom. Presented at the IADIS International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2010).
- Martin, J.-P. (1985). *Zum Aufbau didaktischer Teilkompetenzen beim Schüler: Fremdsprachenunterricht auf der lerntheoretischen Basis des Informationsverarbeitungsansatzes*. Narr.
- Marti, P., Lund, H. H., Rullo, A., & Nielsen, J. (2004). Playing with emotions. In *Proceedings of the Annual Conference of the European Association of Cognitive Ergonomics, Ecce 12*.
- Marti, P., Pollini, A., Rullo, A., & Shibata, T. (2005). Engaging with artificial pets. In *Proceedings of the 2005 annual conference on European association of cognitive ergonomics* (pp. 99–106). University of Athens.
- Massive open online course - Wikipedia, the free encyclopedia. (n.d.). Retrieved April 12, 2016, from [https://en.wikipedia.org/wiki/Massive\\_open\\_online\\_course](https://en.wikipedia.org/wiki/Massive_open_online_course)

- Mataric, M. J. (2004). Robotics education for all ages. In *Proc. AAAI Spring Symposium on Accessible, Hands-on AI and Robotics Education*.
- Matarić, M. J., Eriksson, J., Feil-Seifer, D. J., & Winstein, C. J. (2007). Socially assistive robotics for post-stroke rehabilitation. *Journal of NeuroEngineering and Rehabilitation*, 4, 5.
- Matarić, M. J., Koenig, N., & Feil-seifer, D. (2007). Materials for enabling hands-on robotics and stem education. In *AAAI AAAI Spring Symposium on Robots and Robot Venues: Resources for AI Education*.
- Matsuzoe, S., & Tanaka, F. (2012). How smartly should robots behave?: Comparative investigation on the learning ability of a care-receiving robot. In *RO-MAN, 2012 IEEE* (pp. 339–344). IEEE.
- McDermott, R. P. (1993). In S. Chaiklin & J. Lave, *Understanding Practice: Perspectives on Activity and Context* (pp. 269–305). Cambridge University Press.
- McKenney, S., & Reeves, T. C. (2013). *Conducting Educational Design Research*. Routledge.
- McNally, M., Goldweber, M., Fagin, B., & Klassner, F. (2006). Do lego mindstorms robots have a future in CS education? In *SIGCSE* (Vol. 6, pp. 61–62).
- Midden, C., & Ham, J. (2009). Using Negative and Positive Social Feedback from a Robotic Agent to Save Energy. In *Proceedings of the 4th International Conference on Persuasive Technology* (pp. 12:1–12:6). New York, NY, USA: ACM.
- Midden, C., & Ham, J. (2012). The Illusion of Agency: The Influence of the Agency of an Artificial Agent on Its Persuasive Power. In M. Bang & E. L. Ragnemalm (Eds.), *Persuasive Technology. Design for Health and Safety* (pp. 90–99). Springer Berlin Heidelberg.
- Miettinen, R. (2000). The concept of experiential learning and John Dewey's theory of reflective thought and action. *International Journal of Lifelong Education*, 19(1), 54–72.
- Miller, G. (1984). *Persuasion: new directions in theory and research*. Sage.
- Miller, S. A., & Brownell, C. A. (1975). Peers, Persuasion, and Piaget: Dyadic Interaction between Conservators and Nonconservers. *Child Development*, 46(4), 992–997.
- Mitnik, R., Nussbaum, M., & Soto, A. (2008). An autonomous educational mobile robot mediator. *Autonomous Robots*, 25(4), 367–382.
- Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J.-J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, 1, 209–0015.

- Mumm, J., & Mutlu, B. (2011). Human-robot proxemics: physical and psychological distancing in human-robot interaction. In *Proceedings of the 6th international conference on Human-robot interaction* (pp. 331–338). ACM.
- Nakamura, J., & Csikszentmihalyi, M. (2014). The Concept of Flow. In *Flow and the Foundations of Positive Psychology* (pp. 239–263). Springer Netherlands.
- New Friends 2015. (2015).  
Retrieved March 26, 2016, from <http://newfriends2015.org/>
- OECD. (2015). *Students, Computers and Learning: Making the Connection*. Paris, France: OECD Publishing.
- Oinas-Kukkonen, H., & Harjumaa, M. (2008). A Systematic Framework for Designing and Evaluating Persuasive Systems. In H. Oinas-Kukkonen, P. Hasle, M. Harjumaa, K. Segerståhl, & P. Øhrstrøm (Eds.), *Persuasive Technology* (pp. 164–176). Springer Berlin Heidelberg.
- Papert, S. A. (1980). *Mindstorms: Children, Computers, And Powerful Ideas*. Basic Books.
- Papert, S., & Solomon, C. (1972). Twenty things to do with a computer. *Educational Technology*, 12(4), 9–18.
- Persuasive Technology. (2016). Persuasive Technology 2016 | The 11th International Conference on Persuasive Technology. Retrieved April 8, 2016, from <http://persuasive2016.org/>
- Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In D. E. Kanter & M. Honey, *Design, Make, Play: Growing the Next Generation of STEM Innovators*. Routledge.
- Petty, R. E., & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of Persuasion. In *Communication and Persuasion* (pp. 1–24). Springer New York.
- Piaget, J. (1932). The moral judgment of the child. *London: Kegan, Paul, Trench, Trubner, & Co.*
- Piaget, J. (1954). *The Construction Of Reality In The Child*. Routledge.
- Räisänen, T., Oinas-Kukkonen, H., & Pahlila, S. (2008). Finding Kairos in Quitting Smoking: Smokers' Perceptions of Warning Pictures. In H. Oinas-Kukkonen, P. Hasle, M. Harjumaa, K. Segerståhl, & P. Øhrstrøm (Eds.), *Persuasive Technology* (pp. 254–257). Springer Berlin Heidelberg.
- Reason, P., & Bradbury, H. (2001). *Handbook of Action Research: Participative Inquiry and Practice*. SAGE.



- Reich-Stiebert, N., & Eyssel, F. (2015). Learning with Educational Companion Robots? Toward Attitudes on Education Robots, Predictors of Attitudes, and Application Potentials for Education Robots. *International Journal of Social Robotics*, 7(5), 875–888.
- Resnick, M., Berg, R., & Eisenberg, M. (2000). Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *The Journal of the Learning Sciences*, 9(1), 7–30.
- Resnick, M., & Rosenbaum, E. (2013). Designing for tinkability. *Design, Make, Play: Growing the next Generation of STEM Innovators*, 163–181.
- Rieber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research and Development*, 44(2), 43–58.
- Ringtved, U. L., & Milligan, S. (2015). Trust, technology affordances and feedback in peer assessments in MOOCs. In *Exploring the Material Conditions of Learning - The Computer Supported Collaborative Learning (CSCL) Conference 2015* (pp. 813–14). Göteborg, Sverige: Computer Supported Collaborative Learning Conference, CSCL 2015.
- Roberts, A. S., & Shore, S. M. (2013). Playing with a robot: Enhancing social communication & interaction. In *Proceedings of the International Meeting for Autism Research*.
- Robins, B., Dautenhahn, K., & Dickerson, P. (2009). From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot. In *Advances in Computer-Human Interactions, 2009. ACHI'09. Second International Conferences on* (pp. 205–211). IEEE.
- Robins, B., Dautenhahn, K., Te Boekhorst, R., & Billard, A. (2004). Effects of repeated exposure to a humanoid robot on children with autism. In *Designing a more inclusive world* (pp. 225–236). Springer.
- ROBO-PHILOSOPHY. (2016). ROBO-PHILOSOPHY. Retrieved March 26, 2016, from <http://conferences.au.dk/robo-philosophy/>
- Ros, R., Nalin, M., Wood, R., Baxter, P., Looije, R., Demiris, Y., ... Pozzi, C. (2011). Child-robot interaction in the wild: advice to the aspiring experimenter. In *Proceedings of the 13th international conference on multimodal interfaces* (pp. 335–342). ACM.
- Roubroeks, M. a. J., Ham, J. R. C., & Midden, C. J. H. (2010). The Dominant Robot: Threatening Robots Cause Psychological Reactance, Especially When They Have Incongruent Goals. In T. Ploug, P. Hasle, & H. Oinas-Kukkonen (Eds.), *Persuasive Technology* (pp. 174–184). Springer Berlin Heidelberg.

- Roubroeks, M., Ham, J., & Midden, C. (2011a). When Artificial Social Agents Try to Persuade People: The Role of Social Agency on the Occurrence of Psychological Reactance. *International Journal of Social Robotics*, 3(2), 155–165.
- Roubroeks, M., Ham, J., & Midden, C. (2011b). When artificial social agents try to persuade people: The role of social agency on the occurrence of psychological reactance. *International Journal of Social Robotics*, 3(2), 155–165.
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68–78.
- Salter, T., Werry, I., & Michaud, F. (2008). Going into the wild in child–robot interaction studies: issues in social robotic development. *Intelligent Service Robotics*, 1(2), 93–108.
- Sanders, E. B.-N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *Co-Design*, 4(1), 5–18.
- Scassellati, B., Admoni, H., & Mataric, M. (2012). Robots for Use in Autism Research. *Annual Review of Biomedical Engineering*, 14(1), 275–294.
- Schärfe, H., & Bertel, L. B. (2010). Tracing Concepts in Designing for Change. In *The 14th World Multi Conference on Systemics, Cybernetics and Informatics, Proceedings Volume III International Institute of Informatics and Systemics (IIIS)*. Orlando, FL.
- ScienceTalerter. (2015). NAO-robot-camp. Retrieved March 31, 2016, from <http://www.sciencetalerter.dk/da/gymnasium/camps-og-events/nao-robot-camp/>
- Setapen, A., & Breazeal, C. (2012). DragonBot: A Platform for Longitudinal Cloud-HRI. In *Human-Robot Interaction*.
- Shape Robotics. (2016). Shape Robotics. Retrieved March 28, 2016, from <http://www.shaperobotics.com/>
- Sharkey, A., & Sharkey, N. (2012). Granny and the robots: ethical issues in robot care for the elderly. *Ethics and Information Technology*, 14(1), 27–40.
- Shin, N., & Kim, S. (2007). Learning about, from, and with Robots: Students' Perspectives. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on* (pp. 1040–1045). IEEE.

- Short, E., Swift-Spong, K., Greczek, J., Ramachandran, A., Litoiu, A., Grigore, E. C. et al. (2014). How to train your dragonbot: Socially assistive robots for teaching children about nutrition through play. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on* (pp. 924–929). IEEE.
- Sidner, C. L., Kidd, C. D., Lee, C., & Lesh, N. (2004). Where to Look: A Study of Human-robot Engagement. In *Proceedings of the 9th International Conference on Intelligent User Interfaces* (pp. 78–84). New York, NY, USA: ACM.
- Sidner, C. L., Lee, C., Kidd, C. D., Lesh, N., & Rich, C. (2005). Explorations in engagement for humans and robots. *Artificial Intelligence*, 166(1), 140–164.
- Siegel, M., Breazeal, C., & Norton, M. I. (2009). Persuasive Robotics: The influence of robot gender on human behavior. In *IEEE/RSJ International Conference on Intelligent Robots and Systems, 2009. IROS 2009* (pp. 2563–2568).
- Siegel, M. S. (2008). *Persuasive Robotics How Robots Change our Minds*. Massachusetts Institute of Technology.
- Sirkin, D., Mok, B., Yang, S., & Ju, W. (2016). Oh, I Love Trash: Personality of a Robotic Trash Barrel. In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion* (pp. 102–105). New York, NY, USA: ACM.
- Slegers, K., Duysburgh, P., & Hendriks, N. (2014). Participatory Design with People Living with Cognitive or Sensory Impairments. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (pp. 49–52). New York, NY, USA: ACM.
- Social Robotics. (2016). Retrieved March 26, 2016, from <http://icsoro.org/>
- Søndergaard, B. (2013, July 10). Den teknologiske velfærdsrevolution. *Kristeligt Dagblad*. Retrieved from <http://www.kristeligt-dagblad.dk/danmark/den-teknologiske-velfærdsrevolution>
- Sørensen, K. L. (2015, May). Robotter i dagtilbuddet. *Rundt i Randers*, 2015(16), 6.
- SPARC Robotics. (2016). SPARC Robotics | The Partnership for Robotics in Europe. Retrieved March 26, 2016, from <http://sparc-robotics.eu/>
- Statens Institut for Folkesundhed. (2008). KRAM. Retrieved March 31, 2016, from <http://www.sifolkesundhed.dk/Forskning/Sundhedsvaner/KRAM.aspx?lang=da>
- Stibe, A., & Cugelman, B. (2016). Persuasive Backfiring: When Behavior Change Interventions Trigger Unintended Negative Outcomes. In *Persuasive Technology* (pp. 65–77). Springer.

- Takayama, L., & Pantofaru, C. (2009). Influences on proxemic behaviors in human-robot interaction. In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on* (pp. 5495–5502). IEEE.
- Tanaka, F., & Ghosh, M. (2011). The implementation of care-receiving robot at an English learning school for children. In *Human-Robot Interaction (HRI), 2011 6th ACM/IEEE International Conference on* (pp. 265–266). IEEE. R
- Tanaka, F., & Kimura, T. (2009). The use of robots in early education: A scenario based on ethical consideration. In *RO-MAN* (pp. 558–560).
- Tanaka, F., & Kimura, T. (2010). Care-receiving robot as a tool of teachers in child education. *Interaction Studies*, 11(2), 263.
- Tanaka, F., & Matsuzoe, S. (2012a). Children teach a care-receiving robot to promote their learning: Field experiments in a classroom for vocabulary learning. *Journal of Human-Robot Interaction*, 1(1).
- Tanaka, F., & Matsuzoe, S. (2012b). Learning verbs by teaching a care-receiving robot by children: An experimental report. In *Human-Robot Interaction (HRI), 2012 7th ACM/IEEE International Conference on* (pp. 253–254). IEEE.
- Tapus, A., & Matarić, M. J. (2008). User Personality Matching with a Hands-Off Robot for Post-stroke Rehabilitation Therapy. In O. Khatib, V. Kumar, & D. Rus (Eds.), *Experimental Robotics* (pp. 165–175). Springer Berlin Heidelberg.
- The Design-Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, 32(1), 5–8.
- Tikka, P., & Oinas-Kukkonen, H. (2016). RightOnTime: The Role of Timing and Unobtrusiveness in Behavior Change Support Systems. In A. Meschtscherjakov, B. D. Ruyter, V. Fuchsberger, M. Murer, & M. Tscheligi (Eds.), *Persuasive Technology* (pp. 327–338). Springer International Publishing.
- Torning, K., & Oinas-Kukkonen, H. (2009). Persuasive system design: state of the art and future directions. In *Proceedings of the 4th international conference on persuasive technology* (p. 30). ACM.
- Trovato, G., Kishi, T., Endo, N., Hashimoto, K., & Takanishi, A. (2012). A Cross-Cultural Study on Generation of Culture Dependent Facial Expressions of Humanoid Social Robot. In S. S. Ge, O. Khatib, J.-J. Cabibihan, R. Simmons, & M.-A. Williams (Eds.), *Social Robotics* (pp. 35–44). Springer Berlin Heidelberg.

- Trovato, G., Zecca, M., Sessa, S., Jamone, L., Ham, J., Hashimoto, K., & Takanishi, A. (2013). Cross-cultural study on human-robot greeting interaction: acceptance and discomfort by Egyptians and Japanese. *Paladyn, Journal of Behavioral Robotics*, 4(2), 83–93.
- Turkle, S. (2007). Authenticity in the age of digital companions. *Interaction Studies*, 8(3), 501–517.
- Turkle, S. (2011). *Alone Together: Why We Expect More from Technology and Less from Each Other*. Basic Books.
- Vlachos, E., Jochum, E., & Schärfe, H. (2016). Head Orientation Behavior of Users and Durations in Playful Open-Ended Interactions with an Android Robot. In *Cultural Robotics: Robots as Participants and Creators of Culture*. Springer Science+Business Media B.V.
- Vlachos, E., & Schärfe, H. (2012). Android Emotions Revealed. In S. S. Ge, O. Khatib, J.-J. Cabibihan, R. Simmons, & M.-A. Williams (Eds.), *Social Robotics* (pp. 56–65). Springer Berlin Heidelberg.
- Vlachos, E., & Schärfe, H. (2014). Social Robots as Persuasive Agents. In G. Meiselwitz (Ed.), *Social Computing and Social Media* (pp. 277–284). Springer International Publishing.
- Vlachos, E., & Schärfe, H. (2015). Towards Designing Android Faces After Actual Humans. In G. Jezic, R. J. Howlett, & L. C. Jain (Eds.), *Agent and Multi-Agent Systems: Technologies and Applications* (pp. 109–119). Springer International Publishing.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological*. Cambridge, MA: Harvard University.
- Vygotsky, L. S. (1986). *Thought and language (rev. ed.)*. Cambridge, MA: MIT Press.
- Wada, K., Shibata, T., Saito, T., Sakamoto, K., & Tanie, K. (2005). Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. In *Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on* (pp. 2785–2790). IEEE.
- Wada, K., Shibata, T., Saito, T., & Tanie, K. (2004). Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proceedings of the IEEE*, 92(11), 1780–1788.
- Wainer, J., Dautenhahn, K., Robins, B., & Amirabdollahian, F. (2014). A pilot study with a novel setup for collaborative play of the humanoid robot KASPAR with children with autism. *International Journal of Social Robotics*, 6(1), 45–65.

- Walters, M. L., Dautenhahn, K., Te Boekhorst, R., Koay, K. L., Kaouri, C., Woods, S., Werry, I. (2005). The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on* (pp. 347–352). IEEE.
- Walters, M. L., Dautenhahn, K., Te Boekhorst, R., Koay, K. L., Syrdal, D. S., & Nehaniv, C. L. (2009). An empirical framework for human-robot proxemics. *Procs of New Frontiers in Human-Robot Interaction*.
- Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5–23.
- Weizenbaum, J. (1966). ELIZA—a Computer Program for the Study of Natural Language Communication Between Man and Machine. *Commun. ACM*, 9(1), 36–45.
- Weizenbaum, J. (1976). *Computer Power and Human Reason: From Judgment to Calculation*. W. H. Freeman.
- Werfel, J. (2013). Embodied teachable agents: Learning by teaching robots. In *Intelligent Autonomous Systems, The 13th International Conference on*.
- WONDER 2015. (2015). Retrieved March 26, 2016, from <https://icsrwonder2015.wordpress.com/>
- Wonder Workshop. (2016). Wonder Workshop | Home of Dash and Dot, robots that help kids learn to code. Retrieved March 28, 2016, from <https://www.makewonder.com/dash>
- Yang, S., Mok, B. K. J., Sirkin, D., Ive, H. P., Maheshwari, R., Fischer, K., & Ju, W. (2015). Experiences developing socially acceptable interactions for a robotic trash barrel. In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 277–284).
- Yohanan, S., & MacLean, K. E. (2012). The role of affective touch in human-robot interaction: Human intent and expectations in touching the haptic creature. *International Journal of Social Robotics*, 4(2), 163–180.
- Zaga, C., Lohse, M., Truong, K. P., & Evers, V. (2015). The Effect of a Robot's Social Character on Children's Task Engagement: Peer Versus Tutor. In *Social Robotics* (pp. 704–713). Springer.
- Zaga, C., Truong, K. P., Lohse, M., & Evers, V. (2014). Exploring child-robot engagement in a collaborative task.
- Zheng, L. (2015). A systematic literature review of design-based research from 2004 to 2013. *Journal of Computers in Education*, 2(4), 399–420.



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