ORGANISATIE

Designing the future of education: from tutor robots to intelligent playthings

Robots exhibiting social behaviors have shown promising effects on children's education. Like many analogue and digital educational devices in the past, robotic technology brings concerns along with opportunities for innovation. This article is an invitation to reflect on the role that robotic technology, especially tutor robots and intelligent playthings, could play for children's learning and development. The complexity of designing for children's learning highlights the necessity to start a trans-disciplinary discussion to shape the future of education and foster a positive societal impact of robots for children's learning.

Cristina Zaga

Robots in education: opportunities and controversy

Walk in a school or a maker space and you will find robotic technology. You may see a group of children busy prototyping a robot, or learning programming with a robot. You might also see the very first prototypes of tutoring robots: personified robots exhibiting social behaviors and human-like features to support children's learning (see Figure 1 and 2.1).

Robotic technology is transitioning beyond academic research to commercialization. Media and educational specialists present robots as the inevitable staple of the near future class- rooms. If robots are coming and will function autonomously in the classroom, then schools, teachers and parents need to prepare for it. And many are trying to understand whether and how to embrace this paradigm shift.

The key promise is that robotic technologies will relieve overburdened educational systems. Thanks to robots, educational experiences will be more and more personalized to each pupil. Moreover, robotic technology will offer the today-ever-essential technical skills for STEM (Science, Technology, Engineering and Mathematics). Such enthusiasm is pushing more and more for the adoption of robots in schools. However, many express caution and concerns. Policy makers[1] are worried about the implications of robot's autonomy and Artificial Intelligence (AI), especially about the use of data and the way algorithms are designed. Parents swing between the excitement of providing kids with the ultimate advances in education and the worry that robots might condition children to undesired behaviors[2]. One might say that these challenges and concerns will soon fade away. Ultimately, these concerns are due to the novelty of robot technology.

Figure 1. In the picture examples of robots used in educational settings. From left to right: Nao robot (Softbank robotics), Push-one robot (University of Twente) and Dash and Dot (Wonderworkshop, picture by Wonderworkshop (©Wonderworkshop).

Today's classroom technologies like paper, books, blocks, abacuses computers and digital applications were once controversial and feared, very much like robots are now, but they adapted enough to become essential classroom staples. However, unlike analogue and digital technologies, robots are endowed with agency, the ability to autonomously act and interact with the environment and people. As a result, robots are inherently a relational technology potentially able to build social-emotional relationships[3] with children, instead of simply being objects that children manipulate to facilitate learning, like analogue and digital technologies are. Robots actively relate to children to provide instruction, reinforcement and motivation and (with various strategies and techniques) to foster children learning. Given this relation aspects, what role should a robot take in learning, then? So far, most of the robotic applications have embraced a tutoring role modeled on human tutors. Less attention have been given to other applications and paradigms.
In the remaining of the article, we focus on the technical, socio-ethical and pedagogical implications of the application of educational technology with agency: robots. We present the 'status-quo' of educational robotics, tutor robots and, the 'new-comer' intelligent playthings (term coined for the purpose of the article), which are robotic toys and objects promoting open ended and independent learning through play.

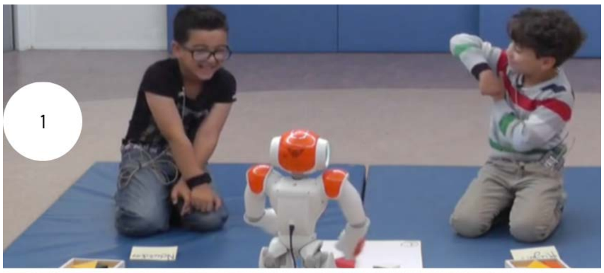

Figure 2.1. A tutor robot interacting with two children taken from Zaga et al. study on the effects of tutor robots on children's task engagement. The robot is a commercially available Nao Robot (SoftBank robotics) one of the most iconic humanoid robot developed in recent years.
Figure 2.2. Intelligent plaything interacting with two children. The robot, or robothing, is a ad-hoc open source research platform developed by Zaga et al. to study how intelligent playthings can support collaborative play © Cristina Zaga.

Tutor robot: the good, the bad and the ugly

Tutoring robots are socio-relational technology that delivers human-like personalized education, using machine learning (and in advanced projects AI) to adapt educational strategies to children. Tutoring robots are personified in a multitude of ways: from human-like puppets/dolls (Figure 2.1), to zoomorphic forms. Whatever form tutoring robots take, one common denominator is the ability to socially engage with children by exhibiting human-like behaviors. Tutoring robots offer an intervention both for typically and non-typically developing children. They stem from virtual computer based agents (think of the famous Clippy, the assistant in Microsoft office). Virtual agents are computer generated, animated characters, usually with distinctive human-like features able to interact mainly via voice and body movement. Similarly to virtual agents, tutoring robots leverage natural language and human-like body language to socially communicate.

Human-robot interaction research has demonstrated that tutoring robots have a competitive advantage over virtual agents due to the higher degree of agency and social presence they deliver. In turns, a tutoring robot's social presence vividly enables a social-relational aspect of learning that has been proved beneficial for children's learning.
Over the last twenty years, many tutoring robots have been developed. According to a recent review of Belpaeme et al., tutoring robots leverage social interaction in three main social roles: teacher, peer and novice peer. These three social roles also represent the three main pedagogical paradigms of a tutoring robot.
Robot teachers were the first tutoring robots to enter the classroom: they model their behaviors on teachers behaviors and try to replicate their pedagogical strategies. The very first robot introduced like a teacher was Robovie (Figure 4.1). In a seminal paper of 2004, Kanda describes how Robovie autonomously delivered English language training to Japanese children.
At the moment, the most popular and versatile robot for education is the Nao Robot from SoftBank Robotics (Figure 1). Nao is a humanoid robot with many degrees of freedom and (some) abilities to understand and respond to natural language, speech, touch and visual stimuli. Nao is used in a variety of applications, from learning mathematics and languages to learning how to manage chronic conditions such as diabetes.

Unlike tutoring robot teachers, robot peers touch-upon the possibility to activate peer dynamics, proven beneficial to learning. Robot peers offer tutoring like a more skilled, empathetic child would do for another child. The Zeno robot platform (Figure 3.1), for instance, has been widely used to develop peer-like interventions: not only with typically developing children learning the ropes of inquiry based learning, but also with non-typically developing children learning about facial expressions. A special kind of robot peers are robot novices. Robot novices, especially the Cowriter robot

1

2

Figure 3.1. The Enigma project robot. The Europen Enigma project further developed the commercially available Zeno robot (Han- son Robotics) to support and empower socio-emotional learning of children on the autism spectrum. DE-ENIGMA is exploring the potential of a robot with artificial intelligence as a near-future tool for autism education.©DE-ENIGMA project.
Figure 3.2. iCat robot used by Leite et al. as learning companion.

(Figure 4.2), flip the power in the teaching dynamics between the child and the robot leveraging what is known as the protégé effect. The child is teaching the robot, who admittedly express his incompetence on a particular subject and request the support of the child to learn about it. Robot novice aim to boost a child's confidence by providing the child with the opportunity to learn through teaching.
On top of the pedagogical strategy and role, tutoring robots have demonstrated a potential to impact children's learning for very specific short-term interventions. Results from various research in human-robot interaction (HRI) show that robots significantly impacted learning outcomes. Robotic tutors have also a positive effect on tangent educational aspects such as student motivation, positive tendency towards learning and curiosity. For example, results indicate that the interaction with a peer-like robot motivates the child to have a growth mindset, a belief that learning is a result of from effort and perseverance as opposed to innate talent. Tutoring robots show potential also to be applied to non-typically developing children, for example with children on the spectrum of autism.

Tutoring robots aim at a great degree of agency and human- likeness both in terms of behavior and (potentially) intelligence. However, many are the technical challenges to render such a human-likeness. The current state of the art of robotics, social signal processing and natural language generation do not afford robot tutors to engage like the human they wish to replicate, and certainly not for sustained, long-term interactions with multiple children. Child-robot interaction often suffers from the mismatch between what children expect the robot could do and what the robot can actually achieve. Carefully designed social behavior for a robot tutor can have unexpected results, such as diminishing the engagement with the robot or even distract from the educational task. Robot tutors are very costly to develop, deploy and maintain. The sophisticated set of human- like behaviors are very costly to render and often, robots break and need to be substituted. Teachers and schools at large most of the time lack of the skills to maintain such technology.
The technical challenges not only impact the performance of tutor robots but also the relations with children. The mismatch between children's expectations and robot capability might bring about a feeling of deception and mistrust that in the long run would be detrimental for the desired educational outcomes.
An ethical layer of concern pertains these complex dynamics between children's expectations of robots with human-like roles, behaviors and appearances and the nature of the relation- ship that a child and tutoring robot could establish in long-term interaction. Research shows that personified, humanlike robots influence children judgment and influence children's behavior. Disappointed by their ability to understand, respond and act in the interaction, children might treat the robots more as a servant or object, or even bully the robots. In turns, treating a robot designed to be human-like and personified 'creature' like a servant or object might have carryover effects on the way children treat adults and other children. Clearly not the intended child-robot interaction.
The promise of tutoring robots is not substituting human- teachers, but complement teacher in their everyday activities. However, by replicating formats and activities that are usual in formal education, tutoring robots might bring more challenges than solutions. Even teachers question the ability of a robot to take a human role and advocate a limitation of the

Figure 4.1. The Robovie Robot. In Figure 4.2. The Co-writer robot. .©The Co-Writer Project

robot's autonomy, wishing for the robot to take a limited complementary pedagogical role supporting overlooked aspects of education such as play among peers. In fact, children learn best through independent discovery, play and interactions with peers and adults. While many advocate playful learning[4], play is still relegated to recess and after-school programs. At the same time, it is while questioning, making, experimenting with objects and toys that children learn about the world, about creativity and problem solving. While establishing play relationship or friendship bonds, children learn from older peers and teach younger ones, meanwhile consolidating their skills. Whilst fundamental for children's development, play is not embedded enough in formal education.
Tutor robots have represented the status-quo of robots in children's education. While many appear to be the benefits of their deployment in the classroom, the designers of tutor robots might opt for a lower degree of autonomy and human-likeness together with a higher degree of control of the child in the interaction to mitigate the many challenges and potential adverse effects on children's development. Together with novel agency models, tutor robots educational activities might benefit for shifting towards playful learning, leaving formal learning to human-teachers.

Intelligent playthings: the power of play

Learning from the experience with tutor robots, HRI researchers are increasingly exploring new forms, roles and pedagogical paradigms for robots in education. Increasingly, robotics applications to children's education are shifting from tutor-like paradigm to an intelligent playthings paradigm, opening new avenues for research and practice.

The research on intelligent playthings stem from the child- centred perspectives of education, the legacy of constructionism and cybernetic intuitions of Edith Ackerman. Constructionism is an active form of learning, where children learn through the experience of doing. Ackerman studied how children makes sense of automated 'things' like robots and advocated a balance between the autonomy of robots and children control to better enable children's natural tendency of engage in playful explorations beneficial to learning.
Focused on learning by doing and in playful interaction, intelligent playthings are autonomous or semi-autonomous robots that resemble educational objects or toys. Intelligent playthings are interactive 'things' with intelligence more than artificial social tutors. As a result, intelligent playthings take a low or non-anthropomorphic form and non- verbal communication capitalizing on the tendency of children (and people at large) to make sense of animate objects in a social way. Intelligent playthings are usually situated in playful tasks and act on children's learning either by autonomously or semi-autonomously playing with the children communicating through goal-directed and expressive actions in the playful interactions.
Intelligent playthings offer an application both for classical school subjects and for socio-emotional learning. The latter is becoming more and more relevant for children's education and a prerogative for the 21st children. The learning through play paradigm has also the potential benefit to readily open the learning experience to peers. The latter has been associated to greater learning achievement in life, better adjustment and to promoting a higher degree of prosocial behavior. The interaction paradigm of intelligent plaything does not revolve around learning

Figure 5.1. Yolo robot Shybo (©The Robot Creativity Project)
Figure 5.2. A rendering of the interactions between children and Cellulo around astronomy games (© Cellulo Project, EPFL).
Figure 5.3. Shybo (© dr. Maria Luce Lupetti)

from instructions, but learning through playing with or along a robot. Therefore, intelligent playthings leave space for a child independent learning, discovering and problem-solving.

Cellulo (Figure 5.2) for example, is an intelligent plaything that blends-in with original educational activities and materials (pen and paper) enabling an interactive experience. Cellulo looks like an hexagon block with small spheres as wheels to affords locomotion and with colorful lights. Whilst Cellulo can autonomously move around, children can also move it around, manipulating it like a piece of puzzle. In one of the application of Cellulo, an astronomy game, Cellulo moves around on a map to indicate relevant content about astronomy. At the same time, Cellulo can also be moved and directed by the child. As depicted in Figure 5.2 Cellulo enables group interaction around learning materials as many children can interact with it at the same time.

Similarly, YOLO (see Figure5.1) is an intelligent plaything that fosters children's creativity in storytelling activities. Yolo moves through locomotion and it expresses itself with lights and movements. Yolo can be manipulated like a toy would and reacts to children play.

Slightly more personified than Cellulo and YOLO, Shybo developed by Lupetti et al., is an open source low-anthropomorphic robot that delivers playful group-learning experiences and supports reflections about the robot's ability to learn from example (See Figure 5.3). Shybo reacts to children with a range of nonverbal behaviors and it has been successfully embedded in teachers' programs as a storytelling interactive object able to engage children in playful exploration of storytelling skills.

Pushone (Figure 2.2), is another example of intelligent play- thing, defined by Zaga et al. as a 'Robothing'. Pushone has a thing-like-appearance, role and behavior and it is em- bedded in various games. Pushone is designed to regulate children's collaboration and conflicts dynamics by stimulating prosocial behaviors (e.g., sharing) in collaborative play. To this end, Pushone engages in the puzzle games with the children. How? It pushes pieces of puzzle around to share them with the children or taking them away. Pushone, by sharing or hiding objects in the game, stimulates reciprocity, discouraging conflict and promoting sharing. Through empirical studies, Zaga et. al. observed that children interacting with Pushone tends to reciprocate more and share resources with each other, especially when the robot exhibits collaborative tendencies.

The research on intelligent playthings is still moving its first steps. Whilst promising, intelligent playthings need to prove themselves as valuable robotic application for learning, Little is known about the actual long-term effects on children learning and the actual feasibility of their deployment in the classroom. Moreover, notable technical challenges arise when robots are moving from one-o-one to one-to-many interactions like in the case of intelligent playthings. Even more challenging is the ability to endow simple, low-cost, sturdy and versatile robots of the computing power necessary to recognize children's behaviors and appropriately engage with them in play.

Despite the above challenges, Zaga argues that intelligent playthings can offer a more versatile educational application of robots in education:

1 - enabling embodied pedagogies and tangible learning, proven as extremely beneficial for children's development,
2 - favoring inclusiveness bridging the interaction between typically and non-typically developed children by virtue of focusing on non-verbal interaction grounded in social play and
3 - integrating school curricula with topics that are often not extensively covered by teachers, like socio- emotional learning, creativity and playful learning.[5]

Conclusion: designing the future of education

Tutor robots and intelligent playthings address needs of con- temporary education in different ways. Intelligent playthings in particular are especially positioned to impact children's education beyond what current technology can offer.

Intelligent playthings, like tutor robots are a relational technology. However, intelligent playthings do not leverage a human-like role to establish relationships with the children. In so doing, the concerns regarding children's mismatch of expectations appear mitigated, as well as some of the ethical concerns about child-robot relationships. In fact, as described by Edith Ackerman, intelligent playthings appear to leverage the natural tendency of children to explore the agency of objects and toys and to establish thing-like relationships typical of children's play interactions which are powerful enablers of learning.

To foster meaningful and rich learning experience for the humans of the future, the development of robots for education should revolve around a child-centred perspective of education. All the societal stakeholders - children included - should come together to have a say in the future of robotic technology for education. To address the complexity of children's education, we, as human factor researchers, need to start a transdisciplinary (i.e., going beyond the boundaries of disciplines to tackle real- world problems) discussion with engineers and AI specialists to shape the future of education and foster a positive societal impact of robots for the children's learning.

Acknowledgments

The article reports research conducted at the Human-Media Interaction group (HMI) of the University of Twente (NL) with dr. Khiet P. Truong and prof. dr. Vanessa Evers and at the Robots in Groups Lab of the Cornell University (USA) with dr. Malte F. Jung.

Disclaimer

References

Edith K Ackermann. 2005. Playthings That Do Things: A Young Kid's 'Incredibles'!. In *Proceedings of the 2005 Conference on Interaction Design and Children (IDC '05)*. ACM, New York, NY, USA, 1-8.

Patrícia Alves-Oliveira, Patrícia Arriaga, Ana Paiva, and Guy Hoffman. 2019. Guide to build YOLO, a creativity-stimulating robot for children. *HardwareX* (2019), e00074.

Alissa N. Antle. 2007. The CTI Framework: Informing the Design of Tangible Systems for Children. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction (TEI '07)*. ACM, New York, NY, USA, 195-202. DOI: http://dx.doi.org/10.1145/1226969.1227010.

Tony Belpaeme, Paul Baxter, Joachim de Greeff, James Kennedy, Robin Read, Rosemarijn Looije, Mark Neerincx, Ilaria Baroni, and Mattia Coti Zelati. 2013. Child-Robot Interaction: Perspectives and Challenges. *Plan. Perspect.* 452 (2013), 459.

Tony Belpaeme, James Kennedy, Paul Baxter, Paul Vogt, Emiel EJ Krahmer, Stefan Kopp, Kirsten Bergmann, Paul Leseman, Aylin C Küntay, Tilbe Göksun, and others. 2015. L2TOR-second language tutoring using social robots. In *Proceedings of the ICSR 2015 WONDER Workshop*.

Tony Belpaeme, James Kennedy, Aditi Ramachandran, Brian Scassellati, and Fumihide Tanaka. 2018. *Social robots for education: A review*. 3, 21) (Aug. 2018), eaat5954.

Olivier A Blanson Henkemans, Sylvia Van der Pal, Ilja Werner, Mark A Neerincx, and Rosemarijn Looije. 2017. Learning with Charlie: a robot buddy for children with diabetes. In *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*. ACM, 406-406.

Catherine C Chase, Doris B Chin, Marily A Oppezzo, and Daniel L Schwartz. 2009. Teachable agents and the protégé effect: Increasing the effort towards learning. *Journal of Science Education and Technology* 18, 4 (2009), 334-352.

Nazli Cila, Iskander Smit, Elisa Giaccardi, and Ben Kröse. 2017. Products as Agents: Metaphors for Designing the Products of the IoT Age. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 448-459.

Kerstin Dautenhahn and Iain Werry. 2004. Towards interactive robots in autism therapy: Background, motivation and challenges. *Pragmatics & Cognition* 12, 1 (2004), 1-35.

Goren Gordon, Cynthia Breazeal, and Susan Engel. 2015. Can children catch curiosity from a social robot?. In *2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 91-98.

Fritz Heider and Marianne Simmel. 1944. An experimental study of apparent behavior. *The American journal of psychology* 57, 2 (1944), 243-259.

Guy Hoffman and Wendy Ju. 2014. Designing Robots With Movement in Mind. *Journal of Human-Robot Interaction* 3, 1 (March 2014), 89-122.

Deanna Hood, Séverin Lemaignan, and Pierre Dillenbourg. 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*. ACM, 83-90.

Hiroshi Ishiguro, Tetsuo Ono, Michita Imai, Takeshi Maeda, Takayuki Kanda, and Ryohei Nakatsu. 2001. Robovie: an interactive humanoid robot. *Industrial robot: An international journal* 28, 6 (2001), 498-504.

Peter H Kahn, Jr, Takayuki Kanda, Hiroshi Ishiguro, Nathan G Freier, Rachel L Severson, Brian T Gill, Jolina H Ruckert, and Solace Shen. 2012. 'Robovie, you'll have to go into the closet now': children's social and moral relationships with a humanoid robot. *Dev. Psychol.* 48, 2 (March 2012), 303-314.

Takayuki Kanda, Takayuki Hirano, Daniel Eaton, and Hiroshi Ishiguro. 2004. Interactive robots as social partners and peer tutors for children: A field trial. *Human-Computer Interaction* 19, 1-2 (2004), 61-84.

James Kennedy, Paul Baxter, and Tony Belpaeme. 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*. ACM, 67-74.

Alexandra Lange. 2018. *The Design of Childhood: How the Material World Shapes Independent Kids*. Bloomsbury Publishing USA.

Iolanda Leite, Ginevra Castellano, André Pereira, Carlos Martinho, and Ana Paiva. 2012. Modelling empathic behaviour in a robotic game companion for children: an ethnographic study in real-world settings. In Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction. ACM, 367-374.

Jamy Li. 2015. The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies* 77 (2015), 23-37.

Michael Luck and Ruth Aylett. 2000. Applying artificial intelligence to virtual reality: Intelligent virtual environments. *Applied Artificial Intelligence* 14, 1 (2000), 3-32.
Maria Lupetti, Yuan Yao, Haipeng Mi, and Claudio Germak. 2017. Design for childrens playful learning with robots. *Future Internet* 9, 3 (2017), 52.
Omar Mubin, Catherine J Stevens, Suleman Shahid, Abdullah Al Mahmud, and Jian-Jie Dong. 2013. A review of the applicability of robots in education. *Technology for Education and Learning* 1, 1 (2013).
Tatsuya Nomura, Takayuki Kanda, Hiroyoshi Kidokoro, Yoshitaka Suehiro, and Sachie Yamada. 2016. Why do children abuse robots? *Interaction Studies* 17, 3 (2016), 347-369.
Ayberk Özgür, Séverin Lemaignan, Wafa Johal, Maria Beltran, Manon Briod, Léa Pereyre, Francesco Mondada, and Pierre Dillenbourg. 2017. Cellulo: Versatile handheld robots for education. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction* (HRI. IEEE, 119-127.
Seymour Papert. 1980. Mindstorms: *Children, computers, and powerful ideas*. Basic Books, Inc.
Hae Won Park, Rinat Rosenberg-Kima, Maor Rosenberg, Goren Gordon, and Cynthia Breazeal. 2017. Growing growth mindset with a social robot peer. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI*. IEEE, 137-145).
Jean Piaget. 2013. *Play, dreams and imitation in childhood.* Routledge.
The Enigma Project. Video Screenshot by University of Nassau Students. https://de-enigma.eu/ features/vlcsnap-2017-04-13-10h09m29s795/.
Aditi Ramachandran, Alexandru Litoiu, and Brian Scassellati. 2016. Shaping productive help-seeking behavior during robot-child tutoring interactions. In *The Eleventh ACM/IEEE International Conference on Human Robot Interaction*. IEEE Press, 247-254.
Kenneth H Rubin, William M Bukowski, and Brett Laursen. 2011. *Handbook of Peer Interactions, Relationships, and Groups.* Guilford Press.
Brian Scassellati, Henny Admoni, and Maja Matari c´. 2012. Robots for use in autism research. *Annual review of biomedical engineering* 14 (2012), 275-294.
Bob R Schadenberg, Dirk KJ Heylen, Vanessa Evers, Christiana Tsiourti, Sten Hanke, and Luis Santos. 2018. Affect bursts to constrain the meaning of the facial expressions of the humanoid robot Zeno. In *Proceedings of the 1st Workshop on Social Interaction and Multimodal Expression for Socially Intelligent Robots* (RO-MAN 2017). 30-39.
Laura Scheepmaker, Christopher Frauenberger, and Katta Spiel. 2018. The Things We Play with Roles of Technology in Social Play. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play.* ACM, 451-462.
Sofia Serholt, Wolmet Barendregt, Asimina Vasalou, Patrícia Alves-Oliveira, Aidan Jones, Sofia Petisca, and Ana Paiva. 2017. The case of classroom robots: Teachers deliberations on the ethical tensions. *Ai & Society* 32, 4 (2017), 613-631.
Bernie Trilling and Charles Fadel. 2009. *21st Century Skills: Learning for Life in Our Times*. John Wiley & Sons.
Vasiliki Vouloutsi, Maria Blancas, Riccardo Zucca, Pedro Omedas, Dennis Reidsma, Daniel Davison, Vicky Charisi, Frances Wijnen, Jan van der Meij, Vanessa Evers, David Cameron, Samuel Fernando, Roger Moore, Tony Prescott, Daniele Mazzei, Michael Pieroni, Lorenzo Cominelli, Roberto Garofalo, Danilo De Rossi, and Paul F M. 2016. Towards a Synthetic Tutor Assistant: The EASEL Project and its Architecture. In *Biomimetic and Biohybrid Systems (Lecture Notes in Computer Science)*. Springer, Cham, 353-364.
Jacqueline M Kory Westlund, Hae Won Park, Randi Williams, and Cynthia Breazeal. 2018. Measuring young children's long-term relationships with social robots. In *Proceedings of the 17th ACM Conference on Interaction Design and Children*. ACM, 207-218.
Randi Williams, Christian Vázquez Machado, Stefania Druga, Cynthia Breazeal, and Pattie Maes. 2018. My doll says it's ok: a study of children's conformity to a talking doll. In *Proceedings of the 17th ACM Conference on Interaction Design and Children*. ACM, 625-631.
Cristina Zaga. 2019. The design of Robothings. Robotic Technology to Regulate Children's Collaboration and Conflict by Stimulating Prosocial Behaviors in Collaborative Play. In *Doctoral Thesis*. University of Twente, in preparation.
Cristina Zaga, Manja Lohse, Khiet P Truong, and Vanessa Evers. 2015. The effect of a robot's social character on children's task engagement: Peer versus tutor. In *International Conference on Social Robotics*. Springer, 704-713.

Abstract

Robots exhibiting social behaviors have shown promising effects on children's education. Like many analogue and digital educational devices in the past, robotic technology brings concerns along with opportunities for innovation. Tutor robots in the classroom are not meant to replace teachers, but to complement existing curricula with personalized learning experiences and one-on-one tutoring. The educational paradigm of tutor robots have insofar limited to replicate models from formal education, but many are the technical, ethical and de- sign challenges to bring this paradigm forward. Moreover, the educational paradigm of tutor robots de-facto perpetuates the exclusion of playful learning by doing with peers and objects, which is arguably the most important aspect of children's upbringing and, yet, the most overlooked in formal education. Increasingly, robotics applications to children's education are shifting from tutor-like paradigm to an intelligent playthings paradigm: to promote active, open-ended and independent learning through play with peers. This article is an invitation to reflect on the role that robotic technology, especially tutor robots and intelligent playthings, could play for children's learning and development. The complexity of designing for children's learning highlights the necessity to start a trans-disciplinary discussion to shape the future of education and foster a positive societal impact of robots for children's learning.

About the author

C. Zaga MSc.
Human Centred Design group, Design Lab, University of Twente Enschede, The Netherlands
c.zaga@utwente.nl

Noten

1. https://en.unesco.org/news/challenges-and-opportunities-artificial-intelligence-education.
2. https://qz.com/701521/parents-are-worried-the-amazon-echo-is-conditioning-their-kids-to-be-rude/
3. https://www.ft.com/content/f3cbfada-668e-11e7-8526-7b38dcaef614.
4. https://www.legofoundation.com/media/1740/learning-through-play-school.pdf.
5. https://www.legofoundation.com/en/learn-how/knowledge-base/.