Thinking with things that learn

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Abstract

This paper investigates the relationship between thinking and the human interaction with things which, in the last decades, was greatly enriched by the diffusion of computational technologies. The analysis of this relationship is reported with a focus on the type of things that might be involved in the interaction, from daily life objects and materials, to computational artefacts, and to computational artefacts able to learn. In particular, machine-learning is presented as an emerging design material able to enhance thinking by fostering a reflection on how machines can learn, on their identity and on the qualities of the input from which they learn.

These considerations are at the basis of an exploration of machine learning as a design material for the development of learning artefacts for children. This investigation was carried out by adopting a Research through Design approach, particularly characterized by practice-based design activities. These consisted mainly in prototyping, from low-fidelity paper mock-ups, to physical computing prototypes, to playing with an open-source machine learning software. This process resulted in the development of two artefacts, Shybo and Pinocchietto, that were used as part of two different playful learning experiences with children in primary schools. The two activities were characterized by a different use of the involved robot. In the first case, Shybo supported a reflection on colours and sounds. In the second case, Pinocchietto was used to reflect on the similarities and differences between machines and humans, and to reflect on the robot functioning by formulating hypothesis and testing them out.

The two artefacts and the related experiences are reported with the aim of contributing to the understanding of the learning ability, machine-learning in this specific case, as a design material to support thinking. To this end, the final part of the article reports observations regarding the activities providing insights about how the artefacts were perceived, children attitude toward the experience, and machine learning features. These observations are also used to introduce also emerging design opportunities.

Keywords: HMI / cognitive ergonomics, HRI, prototyping, machine-learning, design for children.

1 Introduction

Over the last thirty years, the idea of thinking and constructing meaning through the interaction with things was widely addressed by various disciplines, such as semiotics (Keane, 2003), psychology, and anthropology (Henare et al., 2007). In particular, thanks to constructionists' scholars (Ackermann 2004), it became widely acknowledged the idea that thinking and learning are processes that cannot be separated from experience. Especially in childhood, each daily life object and material represents a mean for the construction of knowledge. On the basis of this awareness, many things were, over time, successfully designed specifically for fostering children thinking. Furthermore, the diffusion of computational technologies, which unveiled a wide spectrum of novel learning opportunities, emphasized the things' potential in supporting thinking. As a consequence, several computational artefacts are today employed for supporting thinking and learning, even in educational settings.

Nevertheless, the current advances of artificial intelligence, and its growing availability in the form of novel tools and related documentation, is now opening up again new opportunities. In particular, the availability of open and easy to use software for machine learning enable the design and development of "things that learn", enriching the interplay that may be established between children and things.

Thus, this paper presents an exploration of these current opportunities, grounded on a review of the related research regarding the relationship between things and thinking. The exploration is, then, presented through two case studies, which consist of two robotic artefacts aimed at supporting playful experiences for fostering children's thinking.

2 Thinking with things

Almost thirty years ago, Papert (1980) introduced the concept of "objects-to-think-with". Although already existing and debated in many disciplines, such as semiotics and psychology, this concept helped to point out the role of computers in children learning and thinking. The concept of thinking through the interaction with things, however, goes beyond the use of computers. It is, rather, inherent in human nature.

Thus, this interplay between things and thinking is addressed in this paragraph by reporting three main types of relationships, namely: thinking with daily life objects and materials, thinking with computational artefacts, and thinking with things that learn.

2.1 Thinking with daily life objects and materials

Already at the beginning of the twentieth century, Dewey (1910) was discussing the nature of thought and learning, and how inappropriate it is to separate them from things. The goal of education, in fact, should be to move from concrete to abstract, a process that necessitates the interaction with things, which arouse suggestions and ask for interpretation to children who, in this way, are immersed in inferential processes. This relationship between thinking and things was further investigated by Inhelder and Piaget (1958), who explained the crucial role of objects in the development of logical thinking. From infancy, in fact, people think and elaborate concepts like numbers, space, time, and causality by interacting with objects. Furthermore, these theories were formulated reflecting also on the experiences of the first *kindergarten*, founded by Froebel in 1837 (Resnick, 1998). His work, in fact, represented a determinant contribution to the theories and approaches regarding the things-thinking relationship. He developed a series of 20 tangible objects and materials that he called *Gifts and Occupations* (Provenzo, 2009). These were intended for introducing children to physical forms and relationships that can be found in nature, and their mathematical and logical underlying principles.

Subsequently, a similar approach was adopted by Maria Montessori, who developed a practice-based method to learning, which is still popular today. In her book "*The discovery of the child*" (Montessori, 2015), the author describes the materials specifically designed for supporting various aspects of children's learning, such as sensory education, practical life, reading, writing, mathematics and others. These materials represent a system of objects characterized by some peculiar features. Some aspects of the Montessori's approach were, then, resumed lately by Bruno Munari. Artist and designer, who developed a series of didactic activities for letting children to know and understand art and communication through the direct experience of materials and techniques that might characterise them. He shared with the Montessori approach the idea of isolating features for reflecting through the practice. In particular, the work of the author focused on the sense of touch and through the organization of experimental workshops (Munari, 2005), he developed a method and a series relative *communicative objects* for letting children explore concepts related to form of things and proprieties of materials.

2.2 Thinking with computational artefacts

Although even simple materials are able to foster thinking and learning, computational technologies introduced novel opportunities. Exemplar in this regard is the work by Papert who put into practice the theories by Piaget about learning (Ackermann, 2004), of which, experience is an inseparable aspect (Piaget, 2013), for rethinking education in the digital age. Papert (1980), in fact, explained that more than other technologies, computers can foster the construction of a different type of knowledge, because of their "mathematical nature". In particular, computers can foster the development of what Piaget (2013) called *formal thinking*, in which both the realm of reality and of possibility coexist. Computers can support the construction of knowledge necessary for becoming formal thinkers because it can support two crucial aspects, that are combinatory thinking and self-referential thinking about thinking itself (Papert, 1980).
On the basis of this Papert theories, many projects were then developed with the specific purpose of being "objects-to-think-with", especially at the Lifelong Kindergarten research group, at MIT Media Lab. Resnick (1998) referred to the materials that can be found in Kindergarten, such as Froebel's Gifts and Montessori's materials, as traditional manipulatives for introducing a new type of materials that they called *digital manipulatives*. The aim of these new manipulatives was to provide children with new sets of concepts that can be learned through experience. Some examples are the *programmable building blocks*, consisting of computational technology embedded in LEGO bricks; the *programmable beads*, composed by microprocessors and LEDs, for creating dynamic patterns; the *BitBall*, that can manifest "behaviours" through fading light; and the Thinking Tags, that are interactive badges that exchange users' data when they meet and give a light feedback representing their affinity.
Computational technologies were then embedded into tangible artefacts within the framework of various projects, such as *StarLogo* (Resnick 1996), a programmable modelling environment, *Curlybot* (Frei et al. 2000), a physically expressive computational toy, and *LEGO Mindstorms* (Martin et al. 2000), a robotic construction kit for children that became popular and diffused all over the world. This project assumed a crucial importance in the process of approaching teaching methodologies to practical activities because it was one of the main examples of the potential of educational robots as objects-to-think-with. Today, in fact, the number of educational robotic products is constantly growing, and their employment in contexts like schools is becoming a common practice.
Nevertheless, many other objects' typologies, characterized by responsiveness and non-verbal behaviours, unveiled different types of thinking that objects might support. In particular, Ackermann, in her research about animated toys, that can be both integrated with computational technologies or not, pointed out how an object can be a tool for reflecting on human identity.

In fact, the *AniMates* (Ackermann 2005), as she named the animated toys, are characterized by a certain level of autonomy and present an ambiguous nature, between animate and inanimate. This singular form of agency, that is both surprising and familiar, invite people to establish a relationship with them. As the author explained, *AniMates*, are artificial but also credible and convivial, they seem to have their own will, and their explicit "otherness" compared to humans encourage explorations on psychological issues related to the concepts of agency and identity.

2.3 Thinking with things that learn

The concept of *thinking with things that learn* is grounded in the experiences and knowledge emerged regarding computational artefacts. In this paper, in fact, things that learn are intended as computational artefact characterized by the ability of acquiring new knowledge through a process of training, which can be generalized under the name of machine learning (ML).
This, summarized by Shalev-Shwartz, and Ben-David (2014) as a way to program a computational artefact so that it can learn from available inputs, consists in the study and computer modelling of learning processes (Michalski et al., 2013) that goes beyond the attempt of building automated imitations of intelligent behaviours (Shalev-Shwartz and Ben-David, 2014). ML is rather committed to the use of computing abilities for complementing human intelligence (Shalev-Shwartz and Ben-David, 2014).
Although it is not a novel, neither mysterious, technology (Dove et al., 2017), ML is still little adopted as a design material, and for supporting thinking in relation with its peculiar characteristics. As reported by Dove et al. (2017) referring to user experience (UX) design, the current opportunities offered by the diffusion of resources and tools for leveraging ML potential are often hampered by the difficulties in understanding its actual capabilities, lack of example projects and challenges in deciding when and why the use of ML is purposeful.
Regarding thinking, instead, there is little reference to the use of ML features and peculiarities for supporting children reflection. It is rather common to use ML for improving the efficacy of educational and learning processes. An example is the work by Peterson and Ostendorf (2009) in which ML is used for assessing children's reading level, in the context of foreign language education, and for identifying appropriate readings. Similarly, Gray et al. (2017) used ML for exploring and developing personalized and adaptive learning experiences, that use the data produced during the interaction with an app for tablet for adapting to children learning profile. As previously mentioned, however, these kind of ML applications are not aimed at taking advantage of its peculiarities for fostering learning and reflection, rather for improving didactic approaches. A more thinking oriented use of ML is the one presented by Morris and Fiebrink (2013). The authors, in fact, introduced ML in the educational context as enabling tool, aimed at supporting the learning, mastering and creation of musical instruments and, by doing so, supporting creative learning. A same approach can be noticed within the field of human-robot interaction studies. For instance, Tanaka and Matsuzoe (2012) addressed the theme of second language learning by adopting a learning by teaching approach, in which children were asked to teach to a robot instead of listening to a robot teacher. Other similar examples are the studies by Kory and Breazeal (2014) and by Hood et al. (2015), in which robot learners were developed for fostering children language development in one case, and improving writing skills in another. Nevertheless, despite their use of ML is also focused on improving existing educational processes, these examples introduce the concept of children as teachers which, when dealing with things that learn, become crucial. As stated by Papert (1980), in fact, the act of teaching to a computational artefact how to think allow children to reflect on their own actions and thinking. The concept of teachable agents and their efficacy in supporting learning was largely explored and validated in human-computer interaction studies, see for instance Biswas et al. (2001), Leelawong et al., (2001), and Biswas et al. (2005). The fact of being teachable, however, do

not necessarily mean that these agents are also learners. The act of teaching, in fact, may represent a mere transmission of knowledge. Learning, instead, refers to the act of a process of internal knowledge representation and interpretation (Vermunt and Verloop, 1999). Although this conception refers to the human process of learning, it may be helpful to point out the difference between the teachable nature of many computational artefacts, such as most of educational robots, and the learning ability of artefacts provided of machine learning algorithms. As a matter of fact, teachable computational artefacts may be programmed and instructed for executing sequences of actions, but these are usually based on predefined sets of commands. Things that learn, instead, may build their knowledge from undefined sets of data, establishing inferential processes rather than mere execution. This open nature of the inputs that can be used for training things represent a rich source of stimuli for reflection.

3 An exploration of machine-learning as design material

Given the current availability of easy-to-use and freely accessible tools for machine learning, these were explored as a design material for supporting the design and development of artefacts within the contexts of a research project on the theme of child-robot play. The project was dedicated to the investigation of how edutainment robots might be used to foster reflection and thinking by mediating the interaction of children with the physical environment.

3.1 Methodology

The project was developed by adopting a Research through Design (Frayling, 1993) approach and characterised by an iterative process of making, involving, and situating actions that resulted in the development of two robotic artefacts, shown in figure 1.
In particular, the making actions, oriented to the design and development of artefacts, consisted in prototyping, from low-fidelity paper mock-ups, to physical computing prototypes, and, especially, in playing with an open-source software for machine learning called Wekinator (Fiebrink et al., 2009). More details on this process can be found in Lupetti (2017).
This ML tool enables to easily create things that learn, by providing them a model that can be trained and that can execute a classification algorithm without requiring high technical skills. This can be easily connected to tools commonly used for interactive physical prototyping, such as Arduino boards. In parallel to these making actions, relevant stakeholders were involved in preliminary studies, a questionnaire for parents and a hands-on workshop with children, aimed at informing and inspiring the design process. A description of these activities can be found in Lupetti et al. (2017). Then, the two artefacts developed during the projects were respectively tested as part of two playful learning experiences, carried out in primary schools. These experiences were recorded for subsequent analysis.

3.2 Shybo

Shybo (Figure 1, left) is a small low-anthropomorphic robot that perceives sounds and reacts by lighting up in different colours, and through a minimal nonverbal behaviour, namely the movement of the hat. When sounds are too loud, it gets scared, closes the hat, lights up in red and starts shaking.
It is designed to be used as a character for stories, aimed at supporting children reflection and thinking on phenomena and features of the physical environment or on more abstract concepts, like identity and emotional intelligence. To do so, it is designed to be accompanied by a set of elements that can change and be defined according to the context and the intended activity.
Given the interest in giving control to children, for expressing their visions and interpretations of experiences, the robot has no pre-set colour–sound combinations and children have to train

it to play. The training consists of simple actions: switching modality, selecting a colour, and recording sounds. At the bottom surface of the robot is located a switch that changes the status of the robot from play to train. In this state, the child can select a colour by turning the nose of the robot. Once a colour is chosen, the child can associate a sound to that by pushing the robot's mouth. When the mouth is pushed a small red light indicates that the robot is recording. Once it is released, Shybo automatically saves the association of that sound to the selected colour category. In this way, children can potentially choose to make sound with any kind of object and they can record multiple sounds on the same colour category, paying attention to the similarities of the various sounds.

Figure 1. Left: Shybo in use during a training phase in which a child is selecting a colour to which a group of sounds has to be associated. Right: Pinocchietto with a set of materials that were used during the activities with children.

3.3 Pinocchietto

Pinocchietto (Figure 1, right) is the second version of Shybo and, as such, is able to perceive sounds and to react by lighting up in different colours and by moving the hat. Nevertheless, it is also able to do the opposite: he can perceive colours and react by emitting sounds. The sounds consist of audio tracks saved on the robot's memory that can be associated, potentially by both children or educators, to specific colours through a training process.

The switch for changing the modalities, from training to play, is more visible in this second version since it consists of a yellow switch on the robot back.

Similarly, to the training of sounds on colour categories, soundtrack on the robot memory can be selected and associated to colours that are showed to a colour sensor on the robot, that correspond to one of its eyes.

The robot's motor abilities were also increased. In fact, the expressive movement of the hat was supplemented with the ability of moving around, through a directional movement on wheels. This ability was added for two reasons. On the one hand, the willingness of developing a flexible robot that can be easily adapted to different kind of activities revealed the need for making it "mobile". On the other hand, the ability of moving around is consistent with the idea of using the robot as a character for stories.

4 Playful learning experiences

The development of two robotic artefacts was complemented by the design of two playful learning experiences (Figure 2), which were aimed to be practice-based, explorative and intrinsically motivating (Malone and Lepper, 1987).

In the playful learning approach, in fact, educators, teachers and designers are asked to carry out projects and activities able to support playful experiences by enriching the environment with artefacts that provide experiential learning opportunities, and by supporting and guiding children in their exploration (Fisher et al., 2011). By letting them to explore, children are enabled to interact with things and to reflect on the features and effects of that interaction.
Differently from the examples from the HRI related literature, the things that learn are used in this cases as a 'slow technology' (Hallnäs and Redström, 2001), rather than tools for improving education efficiency. Given the aim of fostering children thinking through the interaction with things, technology is introduced as a thing that takes time to discover its identity, understand its functioning, to try it out, and to see the consequences of an interaction (Hallnäs and Redström, 2001). Thus, both the experiences were focused on the things' ability to learn and invited children to explore this functioning by reflecting on the features of the input data, training, playing and discussing.

4.1 A game with Shybo

The first playful learning experience with Shybo was run in China, at the *Yon Hu Qu Experimental Primary School*, in Yuncheng, in collaboration with X-Studio, from Tsinghua University (China). The experience had a duration of two hours.
In this occasion, Shybo's learning ability was used to design a playful activity for introducing children to simple principles of colour theory and to reflect on sound qualities. To do so, it was introduced to children as *"a small and shy robot that is very curious about sounds, but who doesn't know how to interpret them, and get scared from too much noise"*. The fact of not knowing how to interpret the environment around it, represents the motivation why Shybo needs children's help. In fact, they were asked to train it with the sound of musical instruments for creating a sort of sound-colour code. The central aspect of this activity is that the code resulted from a process on reflection and discussion established by children who had to play the musical instruments, recognize similarities among those sounds and group them accordingly, and then choose colours for the categories. The sound-colour code was, then, used to play a board game that required children to remember the combinations and coordinate in groups.

Figure 2. Left: Children playing a game with Shybo. Right: Children analysing Pinocchietto during the first meeting of the experience "Bringing Pinocchietto Home".

4.2 Bringing Pinocchietto home

The second playful learning experience was designed and developed in collaboration with an organization that offer extracurricular courses to schools in Italy called *10100Percors*i. The experience, carried out in the primary school *Cesare Battisti*, in Turin (Italy), consisted of three meetings, lasted about three hours each. Every meeting was characterised by different activities, supported by different sets of materials. The activities, that engaged twenty children of a fourth-grade class, were specifically designed to create connections with the curricula.
This activity was carried out with Pinocchietto, who got its name from the children who participated. In this case, the ability to learn colours and sounds was used to construct a storytelling in which, again, children were engaged actively as helpers. In this case, the robot was introduced through a small story according to which it was found casually close to the school by the educator. Given its unknown functioning and origin, children were asked to investigate it by using a set of materials, such as coloured cardboards and a magnifying glass, and following some suggestions for the analysis listed in a form. By following the form, children were able to find out the main features of the robot, namely the ability of perceiving sounds and colours, and the fact that colours are associated with memories, expressed through soundtracks. By focusing on its abilities and on its memories stored in the form of soundtracks, children reflected on why Pinocchietto stored data in a certain way, way it was recognizing certain colours while others not and on how did it arrive in front of the school. By doing so, they also reflected on its nature, between the animate and inanimate, making hypotheses on its cognitive and emotional abilities, and comparing it with other things from the artificial and the natural worlds.

4.3 Selection and participation of children

The first playful learning experience was carried out involving twelve Chinese children aged about seven years. They were half females and half males. The children were selected by the teachers of the school from different classes with the intent of not to influence the curricular activity. The parents of the participating children were informed and asked to sign a consent and release form, for the participation of their children. Through the form, they were also asked to agree to the recording of the experience and use of the videos for research purposes and dissemination.
In the second experience, carried out in Italy, the participants' sample consisted of a fourth grade class of a primary school, composed by twenty children aged about 8 years, half females and half males. The class was involved thanks to an existing collaboration between *10100 Percorsi* and a school teacher. Also in this case, parents were asked to sign a consent and release form, for the participation of their children and to agree to the recording of the experience and use of the videos for research and dissemination purposes.

5 Observations and Discussion

The two playful learning experiences were characterized by a slightly different use of the things' ability to learn. On the one hand, it was used to focalize a reflection on features of colours and sounds, and on how the thing might behave by learning colour-sound associations. On the other hand, colours and sounds were used to introduce the concept of memory of the thing. By doing so, aspects of agency and identity were emphasized, and children reflected on how and why the thing was behaving in a certain way.

5.1 Video recordings and storage

Both the experiences were video recorded using an action camera mounted on a tripod and placed on the teacher desk. The videos were recorded for a subsequent analysis, which consisted on an observation and manual coding, supported by Boris (Friard and Gamba, 2016), a behavioural observation tool. The aim was to identify recurring and significant behaviours, considered relevant for assessing enjoyment, concentration and difficulties. The observation of behaviours was complemented by the transcription of children's comments and discussions.
The complete version of the video recordings is privately stored, while brief versions were edited and made available online for dissemination purpose. The can be found at the following links: https://vimeo.com/227591676 (A game with Shybo) https://vimeo.com/251611253 (Bringing Shybo Home).

5.2 Observations

Apart from the level of engagement and enjoyment achieved in the experiences, the analysis of the videos allowed to identify some peculiar aspects related to the act of thinking and reflecting through the interaction with things that learn. These can be summarised in aspects related to children perception of the things, children attitude toward the activity and the robot, and machine learning features.
A first crucial aspect emerged from these observations is that embodying learning abilities might facilitate to *perceive computational artefacts as social agents*. In fact, by reflecting on how and why Shybo and Pinocchietto were memorizing and recognizing inputs, children spontaneously introduced aspects like the thing's motivation and personality.
Regarding the attitude toward the activity and the things, children resulted very *prone to make hypothesis and testing them out,* regarding the things' behaviours, especially in the act of training, they were spontaneously discussing approaches, trying them, commenting each other's opinions. Another aspect relate to the attitude is the fact that children were spontaneously making comparisons and pointing out *similarities and differences regarding how they think and how the things might think*.
Furthermore, children resulted interested and excited by the opportunity of teaching things to Shybo and Pinocchietto. *They wanted to teach them more* skills like speaking, solving math problems, moving around, and also things about their life, like showing them the places they like, especially in the case of Pinocchietto.
These aspects of perception and attitude can be noticed in comments like "*Shybo is angry [...] because we are answering too loudly*" (first experience). Or explanations regarding why Pinocchietto's was reacting to certain colours and not others, like "*maybe it is in a different context that it doesn't recognize*" or "*it has preferences about certain colors*" (second experience). And even other comments focused on the things as social agents like "*when we went to talk to it, it got scared, and then when Micol was talking about it, it moved… maybe it has a bit of feelings*" (second experience).
In addition to children attitude and perception, the things ability to learn resulted positive also from a practical level. The ability of perceiving certain qualities of the environment, like sounds and colours, that can be used to trigger behaviours, opens up the opportunity of *using any kind of existing materials* for crating hybrid experiences. This enabled to easily create a connection between the use of technology and materials that are already present and available in schools. In both experiences, in fact, the robotic artefacts were used together with a set of materials that included musical instruments and coloured cardboards. What was interesting is that, especially in the second experience, children had the chance to try out the Pinocchietto's abilities of recognizing and remembering by showing to the colour sensor of the robot the coloured

cardboards made for the activity, but also by trying out the coloured body of markers and skin of the hands.

Finally, an aspect emerged as crucial regarding the thing-thinking relationship: the error. An error consists in a thing that does not behaves how it is expected to. However, in these cases in which the things have the ability to learn, *an error becomes a misunderstanding*. In fact, in most of cases, it cannot be directly traced to a wrong sequence of inputs, such as with programmable artefacts, rather to perceptual nuances that ask for more training or more contrast among the input data. As a consequence, this mismatch between a desired behaviour and the performed behaviour results in a call for thinking and trying again, in which children are challenged to reflect on the functioning of the learning things and on the properties of the surrounding environment.

6 Conclusions

The process of thinking and learning through the interaction with things is inherent in human nature, as reported by studies in many disciplines, such as psychology and pedagogy.

With the aim of enhancing this process, several projects were developed over time. From manipulatives made of traditional materials like wood, to computational artefacts, today there is a multitude of opportunities for fostering computational thinking, reflection on identity and agency of things. In particular, the possibility of programming computational artefacts revealed, over time, the powerful role that technology might play in supporting children thinking.

The diffusion of freely available and easy to use software for machine learning, today, is opening up even more opportunities in this direction. However, these tools are still little employed as a design material and, especially, as a paradigm from which novel ways of supporting reflection can be built.

Thus, this paper described an exploration of machine learning as a design material for developing things that learn aimed at supporting children thinking, that resulted in two robotic artefacts. Through the observations and the analysis of two experiences carried out in primary schools with the robotic artefacts, it was possible to notice some peculiar aspects that characterised this process of thinking with things that learn.

First of all, the ability to learn can foster children perception of computational artefacts as social agents, because in the act of reflecting on how and why it works in a certain way, children think in terms of thing's motivations and personality. Their attitude, then, is spontaneously curious and investigative. Children formulate, try, and negotiate opinions. By doing so, they compare their own thinking with the thing's thinking. Their positive and active attitude toward the things' ability to learn is also manifested by their willingness to teach them more skills and knowledge. Machine learning resulted also practical because of its ability of supporting resourcefulness. By being used for recognizing features rather than commands, each existing material might be used for interacting and thinking. And a last crucial aspect resulted the mismatch between the expected behaviours and the performed behaviours. Unlike programmable artefacts, this mismatch is considered a misunderstanding rather than an error, opening up further opportunities for thinking.

Thus, these experiences revealed part of the potential of things ability to learn in supporting children thinking. Nevertheless, the two robotic artefacts took advantage of just a little part of the machine learning capabilities, which consisted only in classification algorithms. But machine learning is a broad domain, and by exploring the different learning models further and richer insights will arise. Thus, the domain of things that learn in support of thinking and reflection represents a design space that is worth exploring and which might open up novel ways of looking at the relationship between humans and things.

This relationship, however, brings also out new challenges and ethical dilemmas which will need to be addressed in future research, such as: *to what extent the attribution of emotion, intelligence and intentionality from children can be attributed to socio-dramatic play mindset? How can we take advantage of "the illusion of life" while ensuring transparency and accountability?*

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