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Anthropomorphic Social Robots as Meaning-Making Tools and Peer Models at School

Abstract

This paper discusses the use of anthropomorphic social robots in the area of safety education. The goal of the study was to investigate whether the use of anthropomorphic social robots increases learning efficiency, and if so, why. The underlying assumption was that anthropomorphic social robots may foster meaning-making due to their human-likeness, in particular a discrepancy between their human-like characteristics and the human frame of reference for such traits, and hence to improve learning efficiency. In particular, this paper discusses the results of a qualitative study conducted in four primary schools. The study has shown that the key role of the robot in increasing learning efficiency is not so much to convey information and help carrying out specific tasks as to increase interest, and hence, motivation to learn. Also, the key factors that shape a successful use of such robots in safety education concern as much pupils as teachers and go far beyond the robot as such.

Key words: anthropomorphism, meaning-making, educational robotics, safety education

Antropomorficzne roboty społeczne jako narzędzia tworzenia znaczeń a wzorce rówieśnicze

Streszczenie

Niniejsza praca omawia zastosowanie antropomorficznych robotów społecznych w edukacji w zakresie bezpiecznych zachowań. Celem było zbadanie, czy zastosowanie antropomorficznych robotów społecznych podnosi efektywność nauczania, i jeśli tak, to dlaczego. Podstawowym założeniem było twierdzenie, że antropomorficzne roboty społeczne mają potencjał wspierania procesu tworzenia znaczeń dzięki podobieństwu do człowieka, zwłaszcza poprzez rozbieżność pomiędzy cechami robotów naśladującymi cechy człowieka a ludzkim układem odniesienia dla takich cech. W szczególności niniejsza praca omawia wyniki badania jakościowego przeprowadzonego w czterech szkołach podstawowych. Badanie wykazało, że kluczową rolą robota w procesie podnoszenia efektywności nauczania jest nie tyle przekazywanie informacji i pomoc w wykonywaniu określonych zadań, ile podnoszenie zainteresowania, a przez to motywacji do nauki. Inne czynniki, które wpływają na skuteczne użycie

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antropomorficznych robotów społecznych do nauczania bezpiecznych zachowań, dotyczą tak samo uczniów, jak i nauczycieli oraz wykraczają daleko poza robota jako takiego.

Słowa kluczowe: antropomorfizacja, tworzenie znaczeń, robotyka edukacyjna, edukacja w zakresie bezpiecznych zachowań

Introduction

There has been a wide consensus on the need to modify traditional educational approaches and develop new educational paradigms (Dumont, Benavide, 2010). At the same time, bringing innovation to education has been viewed as a significant challenge, particulary in relation to teaching and learning processes. It has been argued that "Classroom practices (i.e. teaching and learning) are often the most difficult practices of education to change" (OECD, 2014: 25–26). Also, it is important to emphasize that learning is no longer an activity reserved for classrooms, but it is considered a part of lifelong or continuing education (Jarvis, 2004; Kolb, 1976). Since the learning society is still to be created (Jarvis, 2004), the need to bring innovation applies not only to school education but also to lifelong learning. This applies also to robotics and other technologies recently used in schools that often reinforce old ways of teaching and learning rather than inspire critical thinking and creativity, among other skills (Alimisis, 2013).

This work follows symbolic interactionism (Blumer, 1986) to discuss the use of anthropomorphic social robots in education. The novelty of this work lies in using anthropomorphic robots as tools that encourage the process of meaning-making in a given social context. On the one hand, such an approach addresses that concept of meaning-making that has been widely addressed in different constructivist educational paradigms (Au, 1998), including educational robotics (Alimisis *et al.*, 2007; Frangou *et al.*, 2008). On the other hand, this work aims to find new ways to foster human ability to make meanings through the use of anthropomorphism in social robots. Following the symbolic interactionist (Blumer, 1986) and social constructivist perspective (Au, 1998), the meanings are viewed here as constructs that emerge in the course of social interaction. Anthropomorphization is also conceived here as an inherently social phenomenon (Caporael, 1986) that involves both the individual and the society (La Torre, Mudyń, 2014). The underlying assumption is that anthropomorphic robots may foster meaning-making due to their human-likeness, in particular a degree of discrepancy anthropomorphism inevitably brings with it: Human-like characteristics and the human frame of reference for such traits are never the same; also, the very concept of "humanness" defies any definite conclusions. The emphasis on the anthropomorphic discrepancy is in line with the symbolic interactionist thinking, where "As long as action with respect to objects proceeds uninterruptedly, we are unaware of the meaning or content of these objects. When, however, an object calls out conflicting tendencies of action, we are thrown back upon an analysis of (our) spontaneous acts and therefore upon the objects which get their content from them" (Mead, 1900 in: Biesta, 1998: 249). The human ability for reflective and creative thinking is viewed as a distinctively human trait that needs to be developed to enable learning processes over the entire lifetime.

Method

As mentioned above, this study followed the qualitative research approach. While it is possible to employ mixed method approaches and combine different qualitative techniques with, for example, statistical analysis, given the subject of this research, this study employed only qualitative methods. The study aimed at the analytic or theoretical generalization of the findings, which constitutes one of the main approaches towards generalization in qualitative research (Maxwell, Chmiel, 2014; Polit, Beck, 2010). The analytic generalization is a process of generalizing from particulars to broader theoretical constructs (Polit, Beck, 2010) rather than generalization to a population. Also, the study was exploratory in nature. Exploration is a qualitative methodological approach that relies on small research samples and is particularly well-suited for studying the subjects about which there is little or no scientific knowledge available (Stebbins, 2001). This is the case of the use of anthropomorphic social robots in safety education in the role of meaning-making tools which is yet to be understood.

In particular, this study was carried out in the area of safety education in primary schools with the use of the social robot LEMO. The findings of the study served to develop and verify an innovative educational programme (discussion of such a programme goes beyond the scope of this paper). The following sections discuss methods and procedures undertaken within this study as well as its findings.

Participants

In line with the qualitative approach, this research employed a purposive sample strategy, i.e. a non-randomized sample strategy. As a result, the study involved four primary schools. The goal of involving several schools was to ensure variation of samples, which is one of the requirements in purposeful sampling (Koerber, McMichael, 2008). As discussed below, the findings of the data analysis obtained from each school were integrated and analyzed as a whole, without comparing the results between different schools. This was because the goal was to investigate whether the use of the anthropomorphic social robot increases the learning efficiency rather than determines factors that influence the use of such a robot in safety education. All schools were selected based on their proven interest either in safety education or robotics, or both. The classes were conducted as facultative activities in day-care rooms. In each school, the study involved two groups of pupils, namely the group that used the robot (R – Robot) and the group that did not use it (NR – No Robot). All pupils were first-grade pupils who regularly participate in day-care room activities. They were identified and assigned to groups with the help of teachers. Depending on the school, the number of children assigned to a single group varied between 10 and 12 pupils (88 pupils in total).

Methods of Data Collection

The goal of the study was to investigate whether the use of anthropomorphic social robots increases learning efficiency when teaching subjects related to safety education. The underlying assumption was that the use of a social robot in different roles that imply a different degree of anthropomorphism (see Table 1) would require both pupils and teachers to actively make meanings out of the robot's appearance, behaviour and interaction, and hence, improve learning processes. Thus, the study involved subjective and objective measures, i.e. methods that would allow analyzing the degree and nature of anthropomorphization that potentially increases learning efficiency (a–c), as well as knowledge assessment tests that measure learning efficiency. Such an approach relies also on methodological triangulation (Guion, Diehl, McDonald, 2011; Jick, 1979; Shenton, 2004) as it employs two different qualitative methods, namely the interview method (a, b) and participant observation (c).

a) Focus group interview with teachers

In order to address teachers' views on the use of the social robot in the classroom in the context of safety education, all four teachers took part in the focus group interview (given the underlying exploratory research strategy and theoretical generalization, the small sample size was viewed as sufficient). In particular, the goal of the focus group interview was to understand the teachers' perspective on the following issues:

- Perception of the robot and its role in the classroom, including differences, if any, between classes conducted with and without the robot;
- Views on the particular content of lessons and study settings;
- General views on educational robotics and recommendations for future developments in and outside safety education.

The focus group interview is a qualitative technique that involves conducting in-depth group interviews with the participants selected using purposive sampling (Rabiee, 2004). It typically engages smalls groups in an informal discussion and focuses on a specific topic (Silverman, 2010). Due to the group dynamics and interaction, the information obtained from focus groups is often richer than those derived from individual interviews (Rabiee, 2004), which was also the reason for using such a method in this study. Also, it has been argued that when conducting focus group interviews, participants should feel comfortable with each other and they should share similar characteristics (Rabiee, 2004). This was also the case for this study, since all participants were school teachers, they shared similar experience related to the pilot study with the robot LEMO. Also, all of the participants met each other in person, prior to carrying out the lessons.

b) Group interviews with pupils

In all four schools, all pupils who participated in the R groups were invited to take part in a short interview that followed the lesson. The goal of the interviews was to investigate children's perception of the robot in terms of the anthropomorphic effect, i.e. the meanings pupils attributed to the robot's appearance and behaviour, the potential links between such attributions, and the content of lessons (for example, children could depict the robot as human-like in the context of the safety-related exercises). This was to understand the reason the anthropomorphic robots increase learning efficiency, provided such a hypothesis would be positively verified. Also, given only limited writing skills pupils have when completing the first year of school education, interviewing children was viewed as a particularly suitable method. The interview scenario developed for the purposes of interviewing children was significantly shorter than the scenario used in the focus group interview with teachers.

c) Participant observation

In addition to interview methods, this study involved participant observation which had a complementary role with respect to the interviews. All lessons were video recorded and observed by a robot operator and a researcher present in the classroom. Both observers took field notes. The audio-video recording covered the entire duration of lessons to be later analyzed and reviewed to select only those parts that were relevant for the subject of the study and related to the robot (it was not possible to define teachers' and pupils' conduct and the related human-robot interaction a priori).

d) Knowledge assessment tests

In order to explicitly assess the level of learning efficiency, the study involved developing knowledge assessment tests and administrating them among pupils on paper. Given the novelty of educational and social robotics, to the best knowledge of the authors at the time of writing, no other study was conducted in the area of safety education that would employ social robots. Thus, this research involved developing not only specific lesson scenarios and educational aids (see below), but also the content of knowledge assessment tests. The content of such tests was subject to consultation with the teachers and adapted to the pupil's age and educational level, as well as the particular lesson subjects (safety education combined with human--robot interaction) and the underlying qualitative approach. The structure reflected the exercises carried out in the classroom and included such exercises as grouping items in pairs, putting images in order, answering "yes/no" questions, solving a labyrinth with the use of stickers, as well as answering open-ended questions (the latter were limited to only short questions given the limited writing skills children had). Depending on the score, the test allowed illustrating the amount of information memorized in the course of lessons, where some questions allowed more than one correct answer (e.g. house fire can have different causes). Both groups, i.e. group R and NR, were administered the same version of the test. This was made possible by developing a lesson scenario that involved the same set of tasks and teaching aids, where all information and the corresponding tasks could be provided and carried out with or without the robot. Therefore, while the interviews and videos focused on anthropomorphization, the tests were aimed at directly measuring learning efficiency.

Method of Data Analysis

This study employed the thematic analysis method. In general, thematic analysis is a qualitative method used to identify, analyze, and report themes within textual data (Braun, Clarke, 2006). It relies on the coding process which consists of the following steps: coding of data, organizing codes into categories, and using categories to define themes. The coding process is often carried out in two or more cycles, where the second cycle filters and refines the salient features which emerged during the first cycle (Saldaña, 2009). A Theme is the form of capturing a given phenomenon, typically as a phrase or sentence that brings a given unit of data into a meaningful whole. It is important to emphasize that Themes are constructed by the researcher rather than merely found in the data, and the entire process is driven by particular research questions and purposes (Rabiee, 2004). When conducting thematic analysis, there are a number of different methods available for coding data (Saldaña, 2009). The coding methods used in this study included Descriptive Coding used during the First Coding Cycle, Pattern Coding used in the course of Second Coding Cycle, and Simultaneous Coding used in both cycles (for a detailed discussion see (Saldaña, 2009)). Codes and Patterns developed within the coding cycles lead to the development of Themes. Among many different methods to identify Themes across the datasets, this work followed the approach where Themes are identified through "repetitions", and "similarities and differences" (Ryan, Bernard, 2003) are identified within the three datasets.

Recently, the thematic analysis has often been conducted with the use of the software programmes designed to assist in qualitative data management and analysis. This work used NVivo 11 software, which has been commonly used in qualitative research (Bazeley, Jackson, 2013; Marshall, Rossman, 2006).

Procedure

Study Settings

The study was conducted in four primary schools in Warsaw, Poland in the course of one month. The robot used for the purpose of the study was the prototype LEMO designed and produced in Poland. All teachers followed the same lesson scenario developed in collaboration with teachers.

Social Robot LEMO

In general, Human-Robot Interaction (HRI) research involves a variety of approaches towards the anthropomorphic robot design and definitions of the social robot. This work defines the social robot as a physical entity embodied in a human social environment where "interacting with it [a social robot] is like interacting with another person" (Breazeal, 2004). A robot selected for the purpose of this study was the social robot LEMO (see Fig. 1). The main robot's functionalities that facilitate social interaction include the ability to communicate through speech and gestures, as well as to express simulated emotions. The touchscreen, serving as the robot face, and sensors located on the robot head and arms were responsive towards human touch and associated to specific pre-programmed responses. All other verbal and non-verbal behaviours were fully managed by a robot operator.

Fig. 1. Robot LEMO.

When carrying out the lesson, all schools followed the same schedule that covered five days. Depending on the school, the duration of classes in each group varied from 30 to 60 minutes. Such a variation was mainly due to different communication strategies implemented by teachers, as well as the degree of pupils' engagement, who would dedicate a different amount of time to discuss different topics and carry out exercises. Since all groups completed the same set of tasks and related activities, and used the same teaching aids (with the exception of the robot), no specific measure was taken to assess the impact of the duration of the lesson on learning efficiency. In order to limit the potential impact of the teachers' individual characteristics and teaching strategies on the results of the study, in each school the same teacher conducted lessons in both groups, where all teachers were female.

Lesson scenario

The themes addressed in the classroom included 'safe holidays', 'fire prevention, and safety'. Safety education is an obligatory element of primary education in Poland, and is incorporated into the teaching of different subjects. Since safe behaviours take place in the context that often involves a degree of social and physical interaction, anthropomorphic social robots suit safety education well. The theme 'safe holiday' addressed the water safety rules and guidelines for what to do when a child gets lost in public places; the theme 'fire prevention and safety' concerned fire causes and guidelines for evacuation. The selection of themes and dates for the study (prior to the summer holiday) were interrelated.

Each lesson covered a theoretical part and practical exercises. The latter required the use of different educational aids, such as slide presentations and projectors, laminated poster boards, stickers and puppets. This was to allow both teachers and pupils to contextualize the use of the robot in the existing teaching and learning practices, including the use of multimedia devices. In the classrooms where the robot was used, the teacher was in charge of a theoretical discussion while the robot's role was to support such a discussion with specific examples, as well as to help children carry out practical exercises. Depending on the topic and stage of the lesson, the robot was assigned three different roles that corresponded to three different levels of anthropomorphism (see Table 1). The difference between different levels of anthropomorphism was qualitative in nature, with human-robot social interaction being a key component in defining the degree of anthropomorphism: The more anthropomorphic the role of the robot (see 'participant'), the more possibilities for social interaction between the robot and pupils. On the contrary, less anthropomorphic roles (see 'multi-media displayer') imply only limited interactions between the robot and pupils, with only minimum social components of such interactions. Such an approach to a large extent reflected the categories used in educational robotics, where robots are often classified as tools, peers or tutors (Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). The goal of assigning different degrees of anthropomorphism to the robot and its roles was to foster the process of meaning-making and reflective thinking in teachers and pupils, and hence, to improve learning efficiency. The key element in the process

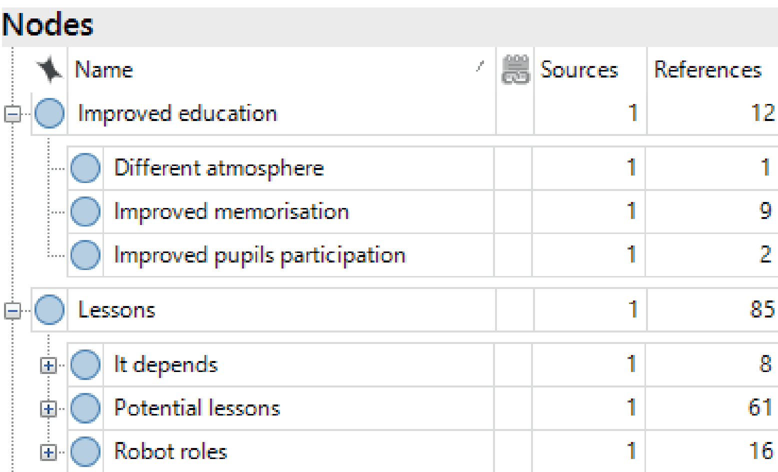
Table 1. The role of the robot and the corresponding degree of anthropomorphism

Role	Description	Interaction	Degree of anthropomorphism
Participant	Exercises concerning evacuation and behaviours when getting lost. The robot would follow the evacuation route prepared by children and find the hidden puppets. In each case, the robot could follow the hints given by the children.	Physical Social Verbal	High
Observer	Children engaged in desk exercises using stickers. The robot observed children, wandered among desks and occasionally commented on their activities.	Social Verbal	Medium
Multi-media displayer	Theoretical discussion led by the teacher. The robot supported the discussion through displaying the images illustrating places and objects related to the safe holiday, fire prevention, and safety.	Physical	Low
	Practical exercises. The robot ran quizzes that required the children to answer "yes/no" by pushing the button on the robot's touchscreen (e.g. to indicate whether a given object may cause the fire or not). Each time a child selected the answer, the robot would confirm whether the answer was correct or not.	Physical Verbal	Low

of meaning-making was the discrepancy between human-likeness in the robot and the human frame of reference (for example, the robot had a face that resembled, but was not exactly, a human face).

Data collection

In each school all lessons were audio-video recorded with the use of two cameras. For the purposes of the analysis, the audio-video recordings were categorized to select and analyze the recordings taken in groups R and related to the robot. Also, all pupils from groups R were invited to take part in the group interviews directly after finishing lessons. The average duration of such interviews was 10 minutes. The focus group interview with teachers was conducted in the week following the completion of lessons in all four schools and it lasted approximately 80 minutes. When conducting the interviews, the moderator followed interview scenarios, as well as addressed other issues brought into the discussion by the study participants. All interviews were conducted in Polish, video recorded, and converted into written transcripts. All three datasets, i.e. the two types of interview transcripts, as well as video recordings were imported to the NVivo 11 software (this applied also to fields notes that were imported in the form of Annotations).


Nodes

Name	Sources	References
Improved education	1	12
Different atmosphere	1	1
Improved memorisation	1	9
Improved pupils participation	1	2
Lessons	1	85
It depends	1	8
Potential lessons	1	61
Robot roles	1	16

Fig. 2. Example of a coding framework created in the programme NVivo 11 for the Focus Group Interview dataset: Nodes correspond to codes, Sources to data, References to the content coded at a given node.

All data was subsequently coded and analyzed using the thematic analysis method. As discussed above, this research involved two Coding Cycles. In particular, the study employed First- and Second Coding Cycle methods, namely Descriptive Coding and Pattern Coding respectively, as well as Simultaneous Coding in both cycles. The First Coding Cycle involved the use of Provisional Coding and Simultaneous Coding method. This included applying the template of Provisional Codes developed prior to data collection and applied to all three datasets, that was later modified in the course of coding. Following Saldana's approach (Saldaña, 2009), the process of coding relied on grouping the pieces of data together based on their similarity and regularity. The main coding unit was a sentence and coding was done line-by-line (Charmaz, 2006). Since many passages were of rich meaning and contained notions that could fall in more than one category, coding was done also with the use of Simultaneous Coding, that allows coding a given passage using more than one code. The Second Cycle relied on Pattern and Simultaneous Coding and it included analyzing and clustering codes developed within the First Coded Cycle into larger categories.

While the process of coding and analysis was carried out for each dataset separately (see Table 2), all three datasets were ultimately brought together (see Table 3) and the formulation of Themes was based on all three datasets addressed as a whole.

Results

The following section discusses the outcome of knowledge assessment tests as well as the main trends identified in the process of coding within and between the three datasets.

Outcome of Knowledge Assessment Tests

As discussed above, all pupils were asked to fill in tests that would assess their knowledge gained in the classroom with regards to 'safe holiday' and 'fire prevention and safety'. The average percentage of correct answers registered in all schools was 85% and 81% for groups R and NR. While in two schools the group R was awarded a higher score than the group NR, in one of the schools an opposite trend emerged, and another school recorded similar results for both groups. In order to provide a detailed explanation of possible factors that led to such differences, the study would require further investigations (as discussed above, the study addressed all four schools as a whole, and it did not compare the findings against each other). For the purposes of this research, it is interesting to note that in most schools children achieved high test scores, independently of the group R vs NR. Such a situation might have occurred due to the following factors:

- Both groups found the lesson content interesting;
- Tests were too easy.

This is because both groups R and NR used educational aids they typically use only to a limited extent (see above) and carried out the tasks that were new to them (T: "It was so refreshing, so different"[2]). Also, given the lack of agreement concerning methodology of the pupils' assessment in educational robotics, the content of the knowledge assessment tests was exploratory in nature, and hence, it may require further improvements. In any case, according to the teachers, the robot helped the

[2] All the quotations have been translated from Polish by the authors themselves. The letter "T" stands for "Teachers" and "P" for Pupils.

pupils to better memorize information obtained in the classroom, and children continued to mention the robot long after finishing the study, including regards to safety education.

Outcome of the Coding Process

Table 2 brings together the results of coding in terms of the main trends developed within each dataset. While teachers' interviews and video recordings included both shared and contradictory trends, the pupils generally shared similar views.

Table 2. Main trends within each dataset

Trends		
Dataset	**Type**	
Interview: Teachers	*Shared*	• Emphasis on the entire institutional and educational context • Increased interest on both the pupils' and teachers' side • Importance of emotional factors in interaction with the robot and education • Distraction as a main issue • Robot as a human-like machine
	Contradictory	• Likeability of the robot • Occurrence of positive vs negative emotional responses towards the robot
Interview: Pupils	*Shared*	• Emphasis on the robot's behaviour • High likeability of the robot • Emphasis on emotional factors related to the robot • Robot as a human-like creation
Audio-Video Recordings	*Shared*	• Teachers: Robot as a means to maintain discipline • Pupils: Touch as a key element of interaction • Both: Robot as a peer • Human-like character of the robot
	Contradictory	• Teachers' approaches towards the robot as a human-like vs machine-like creation • Occurrence of the Uncanny Valley effect among pupils

Also, the following trends were identified between the datasets:

Table 3. Main trends between datasets

Trends	**Dataset**	
	Interview: Teachers	**Interview: Pupils**
Repetitions within dataset	Emphasis on lessons	Emphasis on the robot
Similarities between datasets	Robot behaviour Robot likeability	
Differences between datasets	Robot as a tool Discipline Pretend play	Robot as a peer Play Emotions taken literally

Taken together, the process of coding and theming led to the development of six Themes.

Discussion

The following Themes constitute the key findings of this research:

Teachers as Key Actors

One of the main findings of the study was that it is not only children, but also teachers and their perceptions of the robot that require closer investigation. While children demonstrated rather homogenous attitudes that involved a high degree of anthropomorphization and likeability of the robot, the teachers held much more diversified views of the robot and its role in education, in addition to using different communication strategies and teaching practices. Unlike the pupils, when discussing the use of the robot in the classroom, the teachers addressed the issues that go beyond the robot's appearance or behaviour. While teachers and pupils obviously differ in how they approach the robot, in particular in terms of emotional responses and degree of anthropomorphization, it is the teachers who to a large extent manage the tasks and roles assigned to the robot and encourage specific strategies of meaning-making. For example, the teacher may suggest children touch the robot to greet it, which leads children to pet and hug the robot. Some teachers used the robot and its human-like characteristics as a tool to maintain discipline in the classroom (for example, the robot was described as "sad" due to pupils' misbehaviour). Such an example also proves that the teachers' and pupils' responses to the robot are interrelated: Both of them interact not only with the robot, but also with each other through the robot. Based on the interview, the factors that influenced the teachers' attitudes towards the robot included an individual tendency to anthropomorphize non-humans, a degree of familiarization with technology, safety education, readiness to embrace innovation in education as well as the amount of time and effort needed to prepare and conduct the class. In other words, while teachers are part of larger social networks in a given institutional context, they remain the key actors who bring and manage new tools and practices in the classroom. Several HRI studies addressed the teachers' perspective on the use of robots in education (Alimisis *et al.*, 2007; Serholt *et al.*, 2014; Westlund *et al.*, 2016) and analyzed educational robotics within larger socio-institutional contexts (Alimisis, 2009; Mubin, Stevens, Shahid, Mahmud, Dong, 2013). However, the role of teachers in human-robot interaction and their attitudes towards anthropomorphic robots is yet to be fully understood. The challenge lies not only in investigating the teachers' or children's interactions with robots, but also in analyzing such interactions together.

Institutional and Logistics Context

It was interesting to note that even when using such a novel educational tool as the anthropomorphic social robot, the main teachers' focus was on the practicalities and contextual factors, rather than on the robot as such. First of all, the teachers emphasized the need to obtain support from schools when organizing lessons, in particular from other teachers and, to a lesser extent, parents of pupils. The difficulties in managing the logistics and collaboration with other teachers had direct consequences on the lower likeability of the robot and the lower support for educational robotics. Also, all teachers agreed that conducting classes with the robot as part of obligatory lessons rather than in day-care rooms would give better results. This is because children demonstrate a different level of engagement when participating in the obligatory versus facultative activities. The activities undertaken in day-care rooms generally leave much more free time to children and are less structured. Thus, the main pupils' expectation towards the robot may be that it will play with them, which is not considered "studying" per se. This is an important factor to consider when teaching health and safety-related topics that should not be associated with playful behaviours. Also, the time of the lesson is not without consequences for children performance, since children tend to work better in the mornings, which is also related to the pupils' age. Last but not least, schools vary in terms to what extent they incorporate safety education into the existing teaching programmes, which influenced the degree of familiarization with subjects discussed in the classroom with the use of the robot. While the importance of institutional and organizational factors may seem obvious in education, they have been rarely addressed in the HRI studies. From this perspective, the anthropomorphic robots may foster the ability for meaning-making only if supported by the entire institutional context.

Anthropomorphization as a Conscious vs Unconscious Process

Since children are generally prone to engage in anthropomorphization (Belpaeme *et al.*, 2013), it came as no surprise that pupils to a large extent anthropomorphized the robot. Both the interviews and the video recordings proved that children perceived the robot as human-like, without necessarily overlooking its machine-like parts, in particular the wheels or touchscreen (P: "It has a screen instead of a face"). Only a few pupils paid attention to the robot operator in the classroom. While the analysis of the video recordings conveyed a highly realistic image of the children's interactions with the robot, the interviews proved children were aware the robot was "like a real human being" or "like an average human being" rather than truly human. On several occasions the robot was perceived not so much human-like as life-like: Some pupils explicitly compared it to and treated as a pet and they continued to call it "a robot" or "little robot" rather than by its name "LEMO". One could argue that unlike human-like characteristics, an illusion of animal-like life in the robot was often taken literally by the pupils (P: "He feels what we do and he responds"). At the same time, a few pupils also demonstrated a metaphorical understanding of the robot's behaviour and made fun of it, in the classroom and during the interviews (P: "I'm a robot!"). As far as the teachers were concerned, while some of them addressed the robot in human-like terms and in some cases expressed emotional attachment to the robot (T: "I quickly became friends with him”), they often associated the robot with other technologies and were well-aware of its machine-like character. It was interesting to observe, however, the teachers anthropomorphized the robot to a greater extent when interacting with it in the classroom than when discussing this issue in the course of the interview (there was one exception to that rule where a teacher treated the robot merely as a machine in all situations). For example, the video recordings showed the teachers often referred to the robot’s emotions when speaking about it with the pupils (T: “The robot is happy”) or expressed pity for the robot (T: “Poor LEMO”). Also, they often called it by name, short names included, e.g. “LEMCIO”. Some teachers occasionally petted the robot or encouraged children to applaud it after it successfully completed a task. Most teachers introduced the robot as a “guest”, which may have significantly influenced the children’s expectations and increase anthropomorphization of the robot. The teacher who anthropomorphized the robot the most was consistent in describing it as if it were a person in both the classroom and the interview; even she, however, addressed technical aspects of the robotic systems when discussing the use of robots in schools in abstract. It was also interesting to observe that the role and interaction with LEMO were often described in terms of role-taking, which applied not only to children but also to teachers themselves (one of the teachers mentioned she always enjoys the tasks that require acting). In this sense, the nature of the teachers’ engagement with the robot could be viewed as an example of the willing suspension of disbelief (Duffy, Zawieska, 2012). Also, it is worth noting that the potential to use anthropomorphic social robots in role-taking activities may be useful to teach children to take and consider social roles in emergency situations (e.g. fire or an accident), which often require collaboration with other people. Also, in the context of safety education, role-taking may teach children to take care of not only one’s own safety but also the safety of others. All in all, the differences between reflective and immediate responses to robots are not new to HRI research and they often lead to methodological discussions on the use of questionnaires versus behavioural measurements (Bartneck, Croft, Kulic, 2008). For the purposes of this study, it is important to note that such differences may significantly contribute to the use of anthropomorphic robots as meaning-making tools.

Emotional Factors

An important element of anthropomorphism in the robot’s design and the pupils’ anthropomorphic projections is emotions. Children often expressed positive emotions towards the robot, in particular through petting its head and using diminutives to describe it. Also, most pupils tended to react intensively towards the emotions simulated by the robot. For example, some female pupils would become upset whenever another person, typically a male pupil, would “hurt” LEMO by putting a finger into its eyes. Also, a few kids demonstrated unusual emotional responses which required the teachers to react accordingly. It was interesting to observe that emotions played an important role not only for children, but also for teachers. This was also related to the degree of anthropomorphization, as the only teacher who treated the robot merely as a machine remained also sceptical about the robot's capabilities to engage in emotional interactions with children. In general, the teachers emphasized the importance of emotions in communicating with children, as well as maintaining discipline in the classroom, particularly in primary schools. This may be also related to the fact that all teachers were female: female teachers employ emotion tactics to a greater extent than male teachers (Tonon, 2015). Also, emotional factors may play a particularly important role in teaching how to deal with potentially stressful situations, such as fire emergency or evacuation. The analysis of the video recording proved that on the one hand, the teachers referred to the robot's "emotional states" to capture pupils' attention and guide their behaviours, while on the other hand, one could argue that some teachers attributed emotions to the robot due to pretend play and simply to express their own positive attitudes towards the robot. One of the teachers suggested that the robot could teach courses on emotions. This is how the use of anthropomorphic robots as meaning-making tools may go beyond the meanings understood merely as consciously processed information, and they may be used in and outside safety education. It is important to note, however, that emotional factors are also the element that may cause serious ethical risks since some forms of anthropomorphic discrepancies (e.g. the Uncanny Valley effect) and emotions simulated in the robot may lead to negative experiences in children. As discussed by the teachers, on two occasions the robot caused fear or strong emotional reactions in children. The fact that the robot "felt" pain when a person would put a finger into its eyes, often caused arguments in the classroom and was the only element children perceived as negative when asked about the elements they did not like (the positive aspect arguing about "hurting" the robot was the tendency expressed by some pupils to promote friendly attitudes towards each other). Also, as observed in the video recordings, the robot occasionally generated the Uncanny Valley effect (P: "Zombie!"). In any case, both pupils and teachers generally perceived the robot as "cute" and "cool" and its "emotional states" expressed through facial expressions and speech were the most frequently and vividly discussed elements of the human-robot interaction.

Increased Interest vs Decreased Discipline

In the course of the interview, the teachers often stressed the fact that children found the robot interesting and they memorized better the content of the classes. For example, some children continued to mention the robot when speaking with the teachers, parents or other kids long after the lessons were complete. On several occasions, e.g. in the interviews or conversations with teachers, pupils associated the subject of safety-related behaviours with the robot. However, the teachers also argued that the pupils' interest in the robot may fade away over time. Just as when analyzing other aspects, it was interesting to observe that the robot captured interest not only in children, but also it increased the teachers' interest in running the classes. One teacher argued "the atmosphere was different" and she felt excited about the lessons. Other teachers spontaneously expressed their interest in continuing participation in the study in the future, if possible. It is important to note, that the reason for an increased interest lays not only in the use of the robot, but also in the content of the lessons as such and the interactive nature of exercises. The lesson scenario was generally viewed as stimulating and well-prepared, and different from activities typically undertaken in the classroom. This was particularly true for the tasks that involved physical interaction. Perhaps this is one of the reasons why teachers tended to describe the entire experience mainly in terms of the difference between the facultative versus obligatory classes rather than the difference between the groups R and NR.

At the same time, the increased interest and the corresponding excitement often made it difficult to maintain discipline in the classroom. Children often tried to interact with the robot using the touchscreen, as well as through talking to the robot and calling it by name. One of the most distracting features of the robot was its ability to simulate emotions, in particular to blow kisses. The difficulties in keeping children focused were also related to the facultative, and hence, playful nature of the classes (it has been argued that children's tendency to anthropomorphize robots is generally related to their willingness to engage in play; Belpaeme *et al.*, 2013). Also, as mentioned above, pupils were often distracted due to the particular time of the day and year. How to maintain an appropriate level of discipline is yet to be understood, in particular when teaching subjects related to human health and safety. The video recordings showed that all teachers came up with interesting strategies to improve discipline in the classroom, which often involved a high degree of anthropomorphization. Some teachers pointed to the robot's simulated emotional states to make the pupils behave properly, whether towards the robot or generally in the classroom (T: "He said nobody loves him. Look how sad he is. You should be a little nicer to him"). Also, the robot occasionally served as an observer whose projected role was to assess pupils' work (T: "Look, LEMO is riding and observing whether you are carrying out the tasks properly. Can you see it? He is watching how you are going with the tasks"). Last but not least, the very interaction with the robot was sometimes viewed as a form of an award: When selecting a next pupil to perform the task that requires the pupil to touch the robot's face, some teachers would select persons who "behaved politely". This well illustrates that the anthropomorphic robot has the potential to foster the ability for reflective thinking not only in pupils but also in teachers, where all of them need to agree on specific meanings ascribed to the robot. Also, the robot proved to be particularly suitable for role-taking tasks and it successfully served as a motivational tool that encouraged children to actively engage in the learning tasks and follow teachers' instructions.

Robot as a Peer Model

As mentioned above, the roles assigned to the robot in the lesson scenario varied between a tool, a participant and an observer. It was interesting to note that the dominant approach both pupils and teachers took towards the robot was to treat it as a peer, and hence a human-like participant. The pupils often interacted with the robot using speech and touch and they called the robot by its name or short names. Many pupils were willing to help the robot in carrying out the tasks by guiding it through verbal and non-verbal cues. Some of them would become upset when others would tease the robot by putting fingers into its eyes (the corresponding robot's response was "Ah, it hurts!"). The prevalent tendency was to make sure the robot "feels" good and wants to play with the children and make friends with them (T: "Do you like us"?). In this sense, the robot served as a "peer model" setting an example of how to treat and be friends with other peers, which can also teach collaboration skills in the context of safety risks and emergency situations. While pupils often openly described the robot and interacted with it as if it were a child, such an approach was also present, but less explicit, in the case of teachers. During the interview, some teachers argued that they treated the robot as if it were "one of the kids" or "a member of the group". When analyzing the video recordings, it turned out that the teachers often spoke with the robot, they called it by name and short names, encouraged it verbally to carry out exercises, and occasionally petted its head. All such behaviours could also be observed when interacting with children and the two were sometimes explicitly put together (T: "You did very well, and LEMO did also"). On the one hand, the robot was "forgiven" when it did not "know" how to carry out a given exercise or it bumped into a person or an object, deliberately or not. On the other hand, it was not unusual for both the teachers and pupils to expect the robot to know the right answer and verify the pupil's performance (T: "Let's see what LEMO says. LEMO knows best"; S: "Are we doing fine LEMO? Tell us"). In this sense, the robot was perceived as "an assistant peer" (some teachers explicitly addressed the robot as an "assistant" or "helper"). Also, the teachers occasionally set the robot as an example for children of how to behave properly in the classroom and the robot (or rather its operator) would fit that role by obeying the teachers (T: "Everyone is looking at me. LEMO is also turning towards me. He obeys. Good LEMO"). In this sense, some teachers also conceived the robot as a "peer model".

Limitations and Future Investigations

The main limitation of this study was a small research sample and limited generalizability of the study findings. This was not only due to the use of the qualitative research approach, but also the nature of the phenomena under investigation: teaching and learning processes as well as educational practices vary between schools and individuals (teachers or pupils), and are inherently subjective. This is also true for the process of anthropomorphization which, depending on the individual involved in such a process, may result in a variety of different meanings ascribed to a given robot. Therefore, future research may include larger study samples in terms of the number of schools and pupils, as well as the use of different types of robotic platforms, both anthropomorphic and not. Other potential developments include combining qualitative and quantitative approaches as well as conducting purely quantitative research. Last but not least, the scope of the study may be extended to cover not only safety education but also other subjects that allow for the use of anthropomorphic social robots, as well as enable the participation of students of different abilities.

Conclusions

This study has proved that the anthropomorphic social robots have the potential to encourage the process of meaning-making in both the teachers and pupils, and hence, increase learning efficiency. This was largely due to an increased interest and pupil engagement, and hence, increased motivation to learn. There was a clear link between remembering the robot LEMO and memorizing safety-related information. Also, it was interesting to observe that the meanings most often ascribed to the robot concerned the robot's social roles, in particular the role of the peer. Treating the robot as "a peer model" proved that using robots as meaning-making tools involves not only exploiting the discrepancies between the human-like and human characteristics, but also using the robot as a frame of reference for the human roles and behaviours. It is important to note that meanings are created in the course of interaction between teachers, pupils and the robot rather than only between teachers or children and the robot. This proves that the main potential of educational robotics lies not so much in robots as in the interactions and meaning-making they inspire in human social networks. At the same time, the study has proved that when investigating and designing robot application in education, one needs to address a large variety of factors that go beyond robot specifications and mere human-robot interaction. Therefore, it is human actors and their social context that continue to be the main research focus and challenge.

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