Social Robots in Education

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Abstract

This paper points out some studies which are accomplished with social robots in education and focused on the specific design of the robots in order to be more social. Characteristics and features of a social robot determines the quality of learning and if the learning process will improve or gets interrupted. The most specifications for social robots in education were transferred from intelligent tutoring systems or classic human teachers. The results of the literature review were investigate if they could be implemented in the robot Cozmo to archive a social robot with necessary features for education.

1 Introduction

Robots have been used in various fields such as industry and health care. The benefits of utilising robots are the high availability, reliability and effectiveness. A robot can work 24/7 and deliver always the same quality and with a AI it could increase the own delivered quality every time [3]. In education, the adoptions of robots have been considered since a long time but they were always bound by technical feasibility's. As technology advances, robots can now interact with human and various research indicates promising perspective of adopting robots in education. The role of robots can range from tutoring which provides simple knowledge and information to have an intimate interaction with human. Many researches point out that robots are helpful in education but they are limited with emotional intelligence and preparing its own lessons. The consideration of robots in education should focus on social interaction. Recent study on social robot in education provides an overview and this paper aims to investigate specific characteristics of social robot and the context of social robot usage in education based on literature review.

2 Social robots as learning support

Social robots could support the learning of any student and the age and background from a person does not influence the learning process. For example social robots can help deaf people to learn different signs which was investigated in the study "The Effect of Embodiment in Sign Language Tutoring with Assistive Humanoid Robots" [7]. The results from this study showed that social robots can improve the recognition rate of signs compared to virtual learning strategies. The main advantage of a social robot is the physical presence which can lead to faster completion of any task in a higher quality. The interaction with a social robot is mostly described positive from the participants in most studies [1].
A robot can build up trust with people who interact longer with the robot. A unusual task from a trusted robot would be more likely fulfilled from the interacting person. For example the robot requests the person to place a pile of books in the garbage can which confused the most participants. However many persons still complete the task because they trusted the robot [1].

Physical robots have a higher social acceptance than any on-screen tutor does which leads to another big advantage of social robots in education. The social behavior to any person effects the long-term learning gains. The social behavior motivates the student to learn more besides the regular lessons. The person builds up a relationship towards the robot while interacting with each other [4].
The relationship between social behavior and the outcome of a task is non-linear. In a short term a social robot has some disadvantages because the student has to handle first the new situation and will be distracted from the social behavior. In a long term view the student has great learning gains with a social behavior because he is more motivated to learn [5].
A social accepted robot has its own personal space and it will be respected by the human. People will more likely walk around the robot to pick up something then just replace the robot. The personal space is big at the front and small at the side that's why the engagement towards a human or robot is from the side and not from the front [1].

3 Characteristics and features of social robots presently available in education

Robots can be a enrichment for education when they are supporting a teacher or teaching a person individually. In the last years there where different robots invented for educational purpose. Study's with robots revealed that the social behavior of a robot is important and increases the learning gains [15], [8], [14]. Specific characteristics and features support the socialness of a robot and where investigated in different studies. The tables 1, 2 and 3 are pointing out the important characteristics and features which enhanced learning. In the seven studies they used four different robots which have a different appearance and possibilities.

The most common robot Nao is a human like robot which is shown in the image 1a. Nao is a high developed robot which can be programmed to speak, move and listening. His body has all basic joints in order to move like a human. The only visual difference from a human is his hand which only has three fingers and his face is simply designed which can not express emotion. The participants of most studies used a tablet to go through the tasks and the robot assists the user to solve the task. Nao would be able to communicate without a tablet and be able to teach a class like a human teacher.
The limitation of Nao about the face mimic is the main feature from the robot iCat which is shown in the image 1b. iCat cant do any body movements it is limited to face mimic and its body has similarities with a cat. The robot iCat has speakers to communicate with the user and in order to use the robot iCat a other device is needed for instance electronic chess plate, electronic input cards.
Keepon is a very small yellow snowman-shaped robot which is even more limited as the iCat robot and shown in the image 1c. Its not possible for the Keepon to be social because of its limitation (simplicity). The Keepon

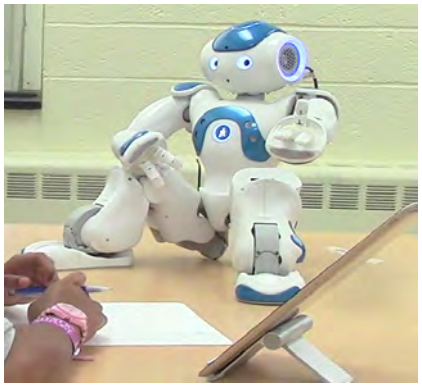
can move its head and bounce on place and it also can interact with a user over a speaker.
Quinn is a social voice-adaptive teachable robot and it was design for the study on "effects of voice-adaption and social dialogue on perceptions of a robotic learning companion" [10]. Quinn is based on LEGO Mindstorms and a iPod for the face which can be viewed in the picture 1d. Quinn is programmed to teach students how to solve math equation problems.

In the study "Higher nonverbal immediacy leads to greater learning gains in child robot tutoring interactions" [6] was the robot Nao used to determine if a social robot should have a low or high nonverbal immediacy. The results showed that a high nonverbal immediacy characteristic has positive effects on children such as increased cognitive learning gains and the children perceive the social robot more like a friend and not a teacher. A low nonverbal immediacy test was also made in order to estimate which characteristics influences the outcome of the task. A high nonverbal immediacy has statistically a better learning outcome and the students did notice if the robot has a high or low nonverbal immediacy.
In a different study with the robot Nao is the main focus the feature productive help seeking behaviour. The participants were divided into two even groups which should prove that a productive help seeking behavior improves learning. The control group got on-demand help where the adaptive group learned with a productive help seeking behaviour but both were learning with the robot Nao. The adaptive group improved significant more than the control group which leads to a much higher test score for the participants where the robot used a productive help seeking behaviour [13].
The robot Nao was also used to determine whether a peer-like character or tutor-like character improves learning more. The results revealed that the peer-like character had a greater focus of attention towards the robot and the task. Also more children solved thy difficulty tasks correctly and fulfilled the tasks faster with the peer-like character. The children which learned with the tutor-like character looked more in the room around rather then focusing on the robot and the task which indicates that the tutor-like character is less effective for solving tasks [15].

The robot iCat was used in the study "Empathic robots for long-term interaction" [8]. It is important for children to emphasize with a robot which keeps the robot and task interesting over a long period of time. To reach this goal a empathic model was developed for a social robot. The empathic model had a positive effect on the interactions between children and the robot iCat. The results showed that the user got more aware of how their actions influenced the behavior of the robot iCat.
The different facial expressions from the iCat are the reason that a other study decided to use the iCat too. The study was about social supportiveness and to show the student empathy takes a important role. The results showed a positive influence of the robots behavior towards the participants and the robot is more socially connected with the student. The users started respect the personal space of the robot which indicates that the robot was socially accepted and treated like a human. [14]

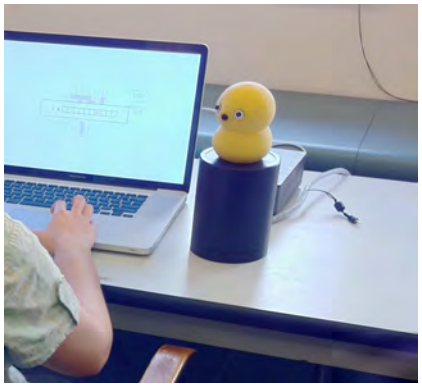
Personalized skill assessment allows Keepon to deliver personalized hints to fulfill a personalized task. This great feature can enhance the outcome and the human-robot interaction. Participants with a supportive Keepon were motivated and solved the task faster than participants without a supportive Keepon. [9]

The self designed robot Quinn showed that the voice adaption with the social dialogue is more effective than only the social dialogue. Female participants react more to the social part as male participants which was the outcome of a interview after working with Quinn. Unfortunately the study can not give results according towards the learning gains because a large number of students passed the post-test with 100%. Still its an interesting feature which could be successful with an advanced voice adaption which includes intensity, speaking rate and vocal quality [10].



(a) Nao [13]

(b) iCat [14]



(c) Keepon [9]

(d) Quinn [10]

Figure 1: Different robots which where tested in different studies

Table 1: Characteristics and features of social robots part 1

Education Field	Robot	students	learning situation	characteristics or features that are helpful for learning	description	reference
math	Aldebaran NAO with tablet	8-9 years old (16 girls, 7 boys)	separate room	nonverbal immediacy	A robot with high nonverbal immediacy has some specific behaviours. The robot leans forward and actively gazes at children while interacting and also does frequent gestures while talking to the user with a normal text to speech implementation. The body is relaxed and moves continuous slightly the upper body.	[6]
math	NAO with tablet	5.-6. grade (13 girls, 16 boys)	separate room	productive help seeking behaviour	A good help seeking behaviour can decrease the usage of hints and increased the learning effect. Therefor they used two strategies for a optimal help seeking behaviour. S1: If the participant makes two consecutive incorrect attempts on a problem without asking for any hints, the robot will automatically provide the participant with the next hint they have not yet requested. S2: If the participant makes three consecutive hint requests on a problem without an attempt in between, the robot will deny the participant the third hint, and request that the participant attempts the problem before asking for more help.	[13]

Table 2: Characteristics and features of social robots part 2

Education Field	Robot	students	learning situation	characteristics or features that are helpful for learning	description	reference
puzzle	NAO	6-9 years old (8 girls, 12 boys)	separate room in couples	peer-like character	The peer-like character was defined by the speech (high pitch, direct and emphatic style), body (sitting postural) and gestures (indication, sweeping, exultation, surprise, grasping). It got a great outcome of the tasks with high completion rate and the time to full fill the task was significantly small.	[15]
chess	iCat	8-9 years old (9 girls, 7 boys)	separate room	empathic model	The empathic model consists of 5 components: Affect Detection, Empathic Appraisal, Supportive Behaviours, Memory of Past Interactions and Action Selection. The robot can use these components in order to emphasize with the user which leads to a positive impact on the interaction.	[8]
language learning	iCat	10-11 years old (9 girls, 7 boys)	separate room	social supportiveness	Social supportiveness increase the learning outcome. There were five social behaviors implemented: role model, non-verbal feedback, attention guiding, empathy and communication skills.	[14]

Table 3: Characteristics and features of social robots part 3

Education Field	Robot	students	learning situation	characteristics or features that are helpful for learning	description	reference
puzzle	Keepon	18-40 years old (80 participants)	separate room	personalized skill assessment	Personalized task and hints improve the learning gains. In this experiment they used two different algorithm to determine the skill level of the participant in order to individualize the lessons conditions. First algorithm is a additive skill assessment which just saved a skill level as Boolean. The second algorithm is used to locate maxima and minima of a skill level. Its called the Bayesian network skill assessment.	[9]
math	Quinn	undergraduate students (24 female, 24 male)	separate room	voice adaptation and social response	The voice adoption manipulates a single acoustic feature pitch. The original text-to-speech output pitch will be shifted up or down in order to acquire a natural voice. Every time before the robot speaks its updating the pitch witch the pitch of the user. The social interaction strategies are divided into three categories: solidarity, tension release and agreeing. The interaction with the robot feels more like a human-human dialogue this leads to a faster acceptance of the robot.	[10]

4 Features of tutoring systems which could improve social robots

There are already many characteristics and features researched for social robots and still there are more features which have to be evaluated with social robots. In table 4 are some features from intelligent or affective tutoring systems listed which would enhance the learning process. Those feature could be implemented in social robots to acquire better results.

A social robot can build up initially a social connection towards the user while describing the declarative instructions. The social connection can build up the motivation and interest from the beginning of the lesson. The perfect timing of feedback could improve the social connection which would support a peer-like character. The student can build up trust that the robot will help him out if he made the task wrong and with the declarative instructions within the feedback the user knows how to manage the problem correctly.

In intelligent tutoring systems has gamification a big influence and a great learning outcome. Gamification for social robots would mean that the environment outside of a single lesson will adopt some gaming features like a reward system. Gamification would not implicate that the robot should be more like a toy to play with. The penalisation of gamification with skill level and individual task was already tested with a social robot [9] which had a positive effect on learning. This success let assume that gamification with social robots improve learning. Gamification has to be investigated with social robots to get reliable results.

A social robot has to have emotions in order to build a social connection with the student which is already researched in different studies like [14], [8], [15]. To recognise emotions from the user is used in affective tutoring systems. The study "Emotion recognition for intelligent tutoring" [12] reviewed different studies with emotion detection in education. The results showed that it is difficult to detect the automatically the emotion from the user. In order to improve the emotion recognition they designed a self-assessment programm which estimates a emotion based on the pleasure, arousal and dominance. If there would be a way for a social robot to recognise emotions it can personalise the task not only based on the knowledge of the user which could enhance the learning gains even more.

Table 4: features of tutoring systems which could improve social robots

features that are helpful for learning	description	reference
timing of feedback and declarative instruction	The perfect timing of a feedback influences the interaction and the learning gains. The most efficient model consists of the following steps. First the students reads the task and identifies goal to reach than the student will plan the actions to accomplish the goals. After the student implements actions he can becomes a feedback. If it is incorrect the student will be provided with instructions to fix the problem. This process will loop until the student succeeded the task. The instructions should consist of some examples of the problem.	[11]
gamification	Gamification is the use of game mechanics and strategies in non-game contexts. Its purpose is to encourage people to use the system and also to keep students more motivated and interested of a long period of time. Most important learning strategies from games are: information on demand; task that are challenging, but manageable; users actions influence the system; initial skill level based on the knowledge of the user; increase skill level with accomplishing specific task and start again with more difficulty tasks.	[2]
emotion recognition	Emotions of a student can affect learning in order to react on the emotions a emotion recognition is needed. The lesson could be more personalized depending on knowledge and the emotional state. Common features of emotion recognition are facial features which can be obtained with a camera. Emotion recognition is a new research area where a lot of research has to be done to work efficiently.	[12]

5 Investigation of the characteristics and features in relation to cozmo

Figure 2: Cozmo

Cozmo is a small robot developed by Anki with an artificial intelligence. The robot got two tires and a big head with a display to show a face, text or images. Cozmo is shown in the image 2 with his special physical feature the fork-lift which can be used to lift up or down a magic cube. There are three magic cubes which are connected with Cozmo and he can recognise and differ between them. A magic cube got on top four LED's, a tap sensor, a accelerometer and on each side a different sign which can be interpreted by Cozmo. The body movements of Cozmo are simple with driving, turning and lift up or down his head and fork-lift. While Cozmo is driving forward he cant fall into the depth because he got a integrated infrared sensor. The social part of Cozmo is more advanced and complex with different reactions on each situations. Cozmo can use many different face mimics, different body colors, his speaker and his body movement to show its feelings and emotions. Cozmo has its own specific voice which can be hard to understand in the beginning which requires a high attention of the user. Cozmo is capable of recognising faces in order to great the user when he sees his face. Cozmo has a free drive mode where he does random actions and can react to user. The reaction could be the face recognition or when he noticed that three cubes are stacked on top of each other than he will get angry and push the cubes until they fall down. The reason why Cozmo gets angry with three stacked cubes is that he could not reach the cube on top because of his physical limitations. Cozmo gives also the opportunity to be programmed with a own code lab from Anki or Python. Cozmo could be programmed to support learning and he can access his already known features. In order to optimise Cozmo for a significant greater outcome he needs more educational characteristics and features.

Cozmo should have a high social supportiveness which is described in the table 2. The level of social supportiveness could be increased by focusing on a fluent and dynamic body motion and gestures. This implies that the emotional behavior towards the students should change in a small interval. Therefore the study describes five important features and characteristics: role model, non-verbal feedback, attention guiding, empathy and communicativeness.
The non-verbal feedback should be programmed with a high nonverbal immediacy characteristic described in table 1. This needs to be modified for Cozmo because Cozmo has physical limitations. Leaning forward while interacting with a student could be changed to driving forward which would imply the same social behavior. Cozmo already can gaze while interacting and doing frequent face mimic while talking. While the student will fulfill the task Cozmo should be programmed to move sometimes in order to relax the learning situation.
If a high nonverbal immediacy is implemented into Cozmo then a peer-like character described in table 2 would be the most suitable role model for Cozmo. Some physical movements can not be implemented with Cozmo, but they could be changed in order to acquire the same social goal. Cozmo needs some empathy to build up a good peer-like connection towards the student. Cozmo can show its empathy with different face mimics and body movements.
The empathy shown by Cozmo can be improved with a complex emphatic model described in table 2. The affect detection can be implemented with the sensors and camera from Cozmo. Depending on the current effective state the implementation has to react with an emphatic response. Then the program has to choose a supportive behavior depending on the memory of the past interactions. Finally Cozmo will perform the best suitable social behavior.
The features voice adaptation and social response described in the table 3 can partly be integrated into Cozmo to support the communicativeness. Cozmo has it's own unique text to speech implementation which would be destroyed with the voice adaptation. A research has to be made in order to decide if Cozmo's text to speech implementation should be replaced or not. The social response can be implemented into Cozmo to build appropriate answers for the students.

Other features and characteristics can also improve the learning gains with Cozmo. The feature of productive help seeking behaviour which is also described in table 1 could be implemented into Cozmo. This feature is only digital and does not relay on any physical interactions. The productive help seeking behaviour can be supported by the high nonverbal immediacy to be more effective towards the user.
Cozmo's memory has to expand by the skill level and quality of the user in order to make a personalized skill assessment which is described in the table 3. Saving the outcome of every task with the user improves the penalization for the next tasks. Also the help-seeking behavior can be improved by showing individual hints for the user. This feature can make Cozmo to a intelligent tutoring robot.

The feature of timing the feedback with declarative instructions (table 4) was implemented in a intelligent tutoring system which could be adopted from Cozmo. Instead of a prompt feedback Cozmo will now use this supportive feature in order to improve the learning gains and a misplaced feedback could be frustrating and demotivating. The feedback with the declarative instruction could also be personalised with the help of the memory about the skill level and its quality.
Gamification would be an interesting feature to implement into Cozmo. Gamification also depends on the memory of the skill level and quality from the user. With the memory its possible to personalise the next task with the suitable difficulty. Also information can be accessed on demand within a task with hints. A reward system could enhance the environment and keep the students long term motivated and interested.
The emotional recognition from table 4 can not be implemented in Cozmo because Cozmo only has a camera with a low quality and other sensors to measure the emotions are required and the automatic emotion detection is not far developed to deliver accurate results.

6 Conclusion and future work

A social robot can improve the learning and should take more place in the education. The social robot would be most efficient if it would be used as a learning companion. The robot cozmo could be programmed to be a social learning companion. In order to be successfull Cozmo should have a high level of social supportiveness. A study with cozmo should be made to confirm that Cozmo can be a great learning companion to enhance the learning. After a study Cozmo could be compared with different robots like Nao or iCat. Finally the question if cozmo could be the first affordable social robot in education for everybody can be answered.

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