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Deploying Social Robots as Teaching Aid in Pre-school K2 Classes: A Proof-of-Concept Study

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Abstract— **This paper describes the outcome of a pilot study of deploying humanoid social robots as a teaching aid in pre-school classroom. Sixteen K2 students each from two pre-schools were recruited to test commercially available robots, Pepper and Nao. The robots were assigned to different schools and were programmed to deliver 6 lessons over a span of 3 months. To assess the deployment and the performance of the children, we used Likert-scale based survey to record our observations. One of the survey forms used was TEPI, which measures the performance of the children's behavior based on three major criteria. The TEPI data gathered suggests that during the lessons children display desirable behavior such as critical thinking, imagination and creativity, and social interaction and independence. We also observed classroom atmosphere, classroom management, and class behavior during the lessons. Data from the survey highlights the potential benefits and the challenges of deploying robots as a teaching aid in a real classroom setting.**

I. INTRODUCTION

As robots become more popular, its application in education is also being explored more. Benitti [1] has highlighted that robots could enhance lessons although there is still no consensus on the exact benefit of using robots. In Benitti's review paper however, most applications of robots in education is in learning programming or robotics itself.

Another application of robots in education is as a teaching tool, much like the role played by information-communication technologies (ICT) devices nowadays [2][3]. These technology-based teaching tools are recognized to enhance children's learning experience and foster the skills and experience needed for the digital age. Robots could play more multi-dimensional role as a tutor, as a learning companion, and as a learning tool [4].

Social robots have been deployed as teaching aid previously such as in language [5][6], literacy [7], numeracy [8], or in learning technology itself [9]. Despite the success of these studies, cautionary feedback also abound, mostly coming from the perspective of the teachers [10][11]. Often the teachers have a different expectation about robots although they may get pleasantly surprised about their experience after deploying robots in classroom [11]. Baxter et. al., [10] has warned that a lot more has to be studied before fully comprehending and tackling the challenges of using robots in classrooms. Issues on pedagogy, methodology, and ethics of using robots in classroom were highlighted in the study [10]. Previous study in deploying robotic puppet in kindergarten has also highlighted the above observations [15].

Fig. 1. Nao and Pepper robots from Softbank Robotics (photo from [12]).

Thus, for this study, we looked at the challenges of deploying social robots in pre-school classrooms from the perspective of both the students and the educators.

II. DEPLOYING ROBOTS IN PRE-SCHOOL

We have taken the view that it is inevitable for robots to become part of our children's education, not as a replacement for teachers but as teaching aids. Social robots could become as common as projectors in classroom, but with more capabilities and benefits. Thus, this study tried to look at the more practical issue of deploying robots. Questions that we wanted to focus on include:

- Are robots going to elicit from the students the behaviors we desire such as critical thinking, creativity, and independence?
- What kind, design, or form of robots would be best to use?

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Fig. 2. The K2 class with the Nao robot.

Fig. 3. The K2 class with the Pepper robot.

- What are the practical issues of deploying robots at mass scale?

To organize our observation, we adopted a measurement scale used to evaluate play materials. This scale is focused on the children's behavior during the lesson. We also determine the perspective of the teachers, principals, and education specialist about the conduct of the lessons.

III. Experiment

A. The Subjects

The K2 classes composed of 5-6 year old students from two pre-schools were recruited to participate in the study. The first school had 16 students while the second one has 32, of which only 16 were included in the study. Photographs and videos of the lessons were taken and observations were recorded through survey. IRB permission was obtained from Nanyang Technological University's IRB Committee to conduct the study.

B. The Social Robots

We used two social robots from Softbank Robotics: Nao and Pepper (see Fig. 1). Nao is a small bi-pedal robot measuring 57.3cm in height and weighs roughly 5kg. It was first released in 2004 and is now a very popular platform; it is used as the standard platform in Robocup [13]. Pepper, which was first released in 2014, is a taller and heavier robot at 120cm and 28kg. Pepper, which has wheels instead of legs, uses the same operating system and software platform as Nao.

Nao and Pepper have similar built-in sensors and accessories such as cameras, microphones, speakers, LED lights, tactile sensors, bumpers (switches), sonars, and ethernet/wifi connectivity. However, Pepper has additional functionalities such as a tablet mounted on its chest, a 3D camera, gyro, IR, and laser sensors. Its battery also lasts for 8 hours compared to Nao's 30 minutes. Each school was assigned a robot to be used for all its lesson for the duration of the project.

C. Lessons Using The Robots

A total of six lessons were created using each robot.

For the Nao robot, the six lessons include:

- Getting to know the robot - a meet and greet lesson between the children and the Nao robot
- Sorting trash - Nao quizzes the children about the trash around it and asks them in which bin to put it
- Cookie dough making - Nao instructs the children the step by step process of making the dough
- Places of interest in Singapore - Nao plays a guessing game with the children on popular places in Singapore
- Me Too - An extension of the previous lesson, the children guess Nao's favorite places in Singapore, and afterwards, Nao and the children compare notes on their favorite things
- What is Singapore - Nao reads a story book about Singapore and asks questions to validate children's understanding of the story

The six lessons for the Pepper robot are:

- The hare and tortoise story - Pepper tells the story about the hare and the tortoise and asks about how the characters would feel at certain points of the story
- Making sound patterns - The children made "music" with the help of Pepper by making patterns from snippets of sounds around the neighborhood
- Supermarket theft - Pepper introduces the different people around the neighborhood (plumber, grocer, etc) through a guessing game. Afterwards, Pepper plays a detective game with the children to identify who stole the money from the supermarket's cash register
- Supermarket self-checkout - With Pepper acting as the cashier, the children scans their purchase using QR codes and pays with coins, which Pepper has to count using its camera.
- Society harmony - Pepper introduces the concept of having a multi-racial society and plays the role of a newcomer in Singapore so that the children could teach it about the rules and norms of society
- Help a friend - Children help Pepper, which plays the role of a new primary school student, adopt to its new environment by helping it against bullies and teaching it about healthy food selection

Figure 2 and Fig. 3 show the two robots during a lesson in their assigned pre-schools. The six lessons were conducted over a period of 3 months.

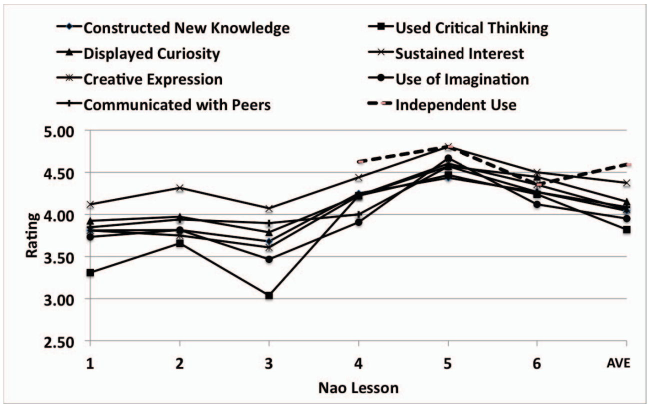

Fig. 4. The mean TEPI score for each Nao lesson across the different behaviors.

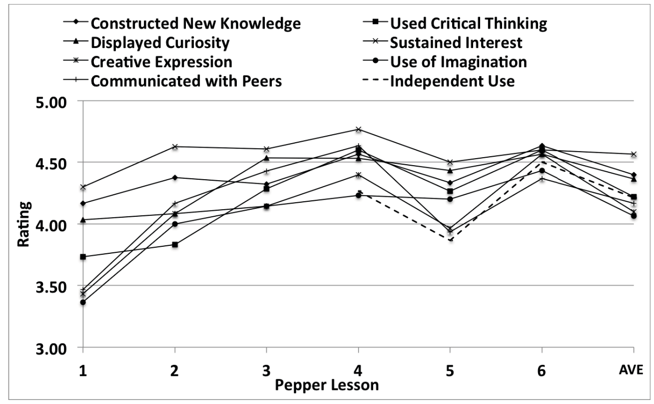

Fig. 5. The mean TEPI score for each Pepper lesson across the different behaviors.

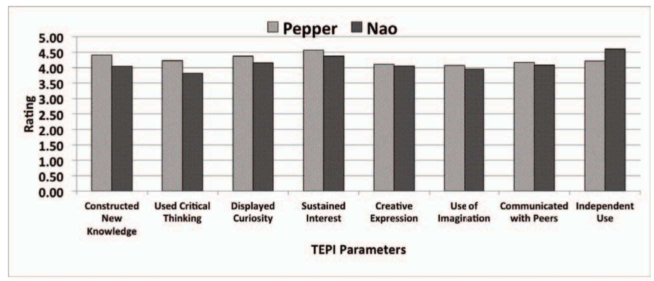

Fig. 6. Comparison of the TEPI scores of both robots.

D. Making The Lessons

The lessons were created by the joint effort of the engineering and the education teams. The engineering team included the content creators, programmers, and engineers. Each school had its own education team composed of the teacher, the principal, a curriculum specialist, and a pedagogy specialist.

The lesson making process was collaborative and iterative:

1) Based on the planned curriculum for the year, the teachers and the principal decides on the lesson topics and agenda.
2) The teacher also makes the initial lesson plan that uses the robot as a teaching-aid.
3) The engineering team checks the initial lesson plan for compliance to robot safety requirements and adherence to the capability and limitations of the robot.
4) The teacher modifies the lesson plan when deemed necessary.
5) The engineering team creates the lesson.
6) Both teams review the first version of the lesson, and when necessary, suggest changes to the lesson to ensure smooth operation at class time.
7) Both teams modify the lesson according to the suggestions.
8) Both teams reviews the lesson one last time for minor adjustments on the scheduled day.
9) The teacher conducts the lesson while the rest observes.

The close collaboration among the stakeholders ensured that the lessons were designed to maximize the robot's capability while adhering to the curriculum of each school.

E. Assessing the Lessons & Robot Deployment

1) TEPI: We have adopted the Toy Effects on Play Instrument (TEPI) scale developed by Trawick-Smith et al. [14]. It measures children's performance on three areas of behavior as they interact with the play instrument (the robot in this case): (1) thinking and learning, (2) creativity and imagination, and (3) social interaction and independence.

There are a total of 8 questions. Under thinking and learning, the four behaviors observed are (a) the ability to construct new knowledge, (b) problem solving skills, (c) the ability to make inquiries, and (d) the ability to keep engaged. Under creativity and imagination, the two behaviors observed are (a) the ability to express creatively and (b) the ability to use imagination. For social interaction and independence, the two behaviors observed are (a) the ability to collaborate and (b) the ability to use the play instrument (robot) independently.

The TEPI scale indicates the performance level or frequency of showing such behaviors. A score of 5 denotes "much expression", 4 means "some expression", 3 denotes "intermittent expression", 2 means "little expression", and 1 means "no signs of expression".

2) Classroom Assessment: While TEPI looks at the performance of each child throughout the lesson, we also assessed classroom performance including classroom atmosphere, classroom management, and aggregate class performance.

The following questions where asked to assess the classroom atmosphere:

- The classroom climate was positive during the lesson.
- The robot was well integrated into the lesson.
- The use of robot in the lesson was appropriate.
- The robot fit into the lesson flow naturally.
- The robot enhanced the lesson in general.
- The robot generated interest from the children about the lesson.
- The robot did not have any technical problems during the lesson.
- The robot helped the children understand the lesson.

For the classroom management we asked the following:

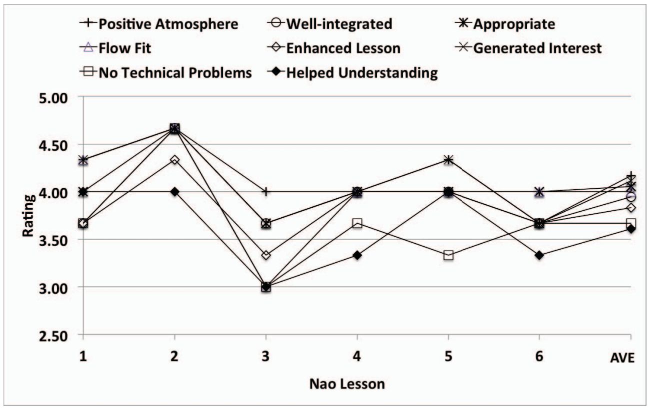

Fig. 7. Scores on classroom atmosphere of the lessons using Nao robot.

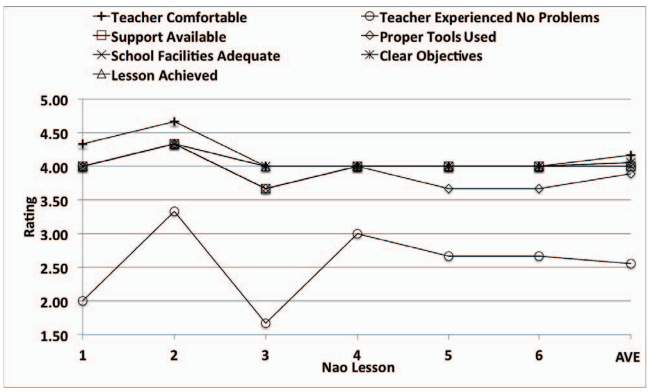

Fig. 8. Scores on classroom management of the lessons using Nao robot.

- The teacher was comfortable in using the robot during the lesson.
- The teacher had some problems (technical and/or non-technical) when using the robot during the lesson.
- Proper support and resources were available to be able to incorporate the robot in the lesson.
- The robot was incorporated into the lesson through the use of proper tools and resources.
- The school facilities and equipment were adequate to support the use of the robot in the lesson.
- The lessons objectives were clear.
- The aim of the lesson was achieved.

The answer is rated similar to TEPI: 1 being equivalent to ”strongly disagree”, 2 is ”disagree”, 3 is ”neither”, 4 is ”agree”, and 5 is ”strongly agree”.

Parametric tests were used to analyze the collected survey data. Four observers, each assigned to 6-8 children every lesson, were trained to use the TEPI. For classroom assessment, three people were asked to fill out the survey including the teacher, the kindergarten principal, and another observer.

IV. Result and Discussion

A. TEPI Scores of Nao and Pepper

With the TEPI survey, we were able to evaluate the behavior of each child as each lesson took place. The TEPI result for the lessons using Nao is shown in Fig. 4 and Fig. 5 shows the data for Pepper. Both figures show the mean of

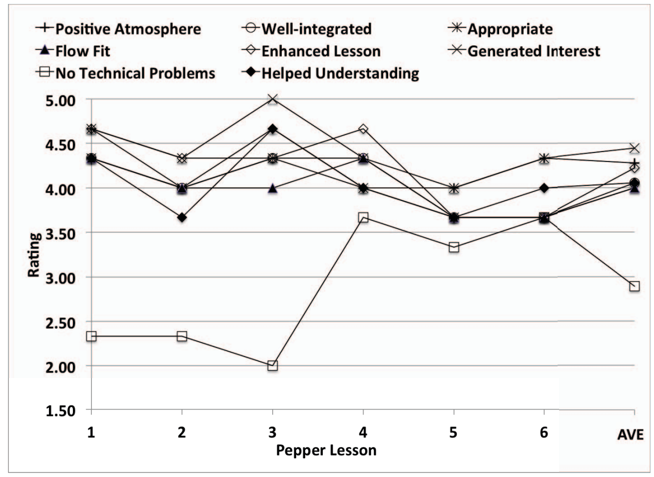

Fig. 9. Score on classroom atmosphere of the lessons using Pepper robot.

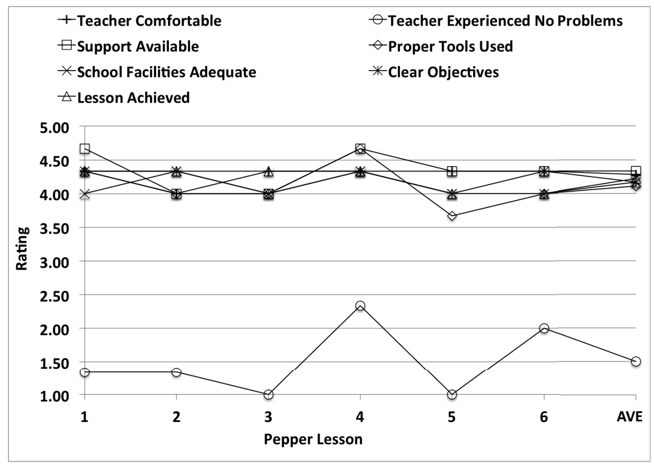

Fig. 10. Score on classroom management of the lessons using Pepper robot.

the gathered TEPI scores for each behavior across the six lessons.

Any score above 3 indicates a positive result (”agree” and ”disagree”); anything below 3 indicates negative (”disagree” and ”strongly disagree”). For both robots the trajectory of the displayed behavior across the six lessons are upwards. This sustained display of positive behavior by the children help rule out ”novelty” as the reason for positive responses during the first lesson.

A noticeable behavior is the child’s display of use of critical thinking during the Nao lessons (see Fig. 4), which dipped on the 3rd lesson. During the third lesson, the children had to simply follow the instructions in making cookie dough as read out by Nao. There was no opportunity for the kids to display critical thinking as the activity was very process-oriented.

The initial scores for both robots are lower than for the rest of the lessons, but this might be explained by the trepidation felt by the children when they first encounter the robot. Interestingly, when the scores are compared side by side (see Fig. 6), both robots show that the children exhibited the desired behavior. Either robot would be useful, but the deciding factor might come from other considerations, not

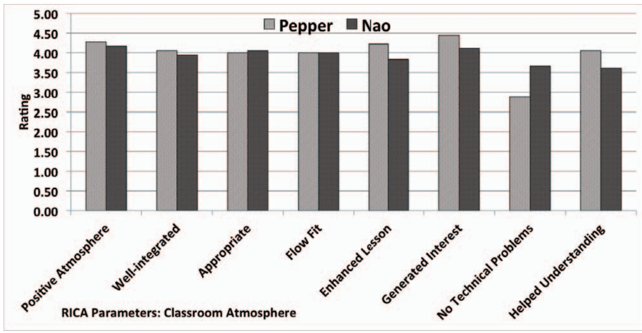

Fig. 11. Comparison of scores on class atmosphere for both robots.

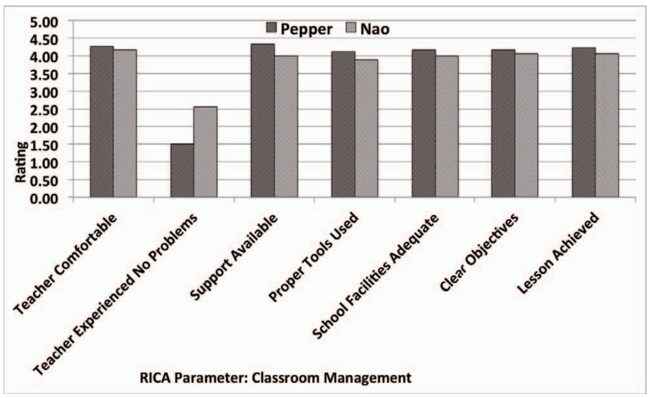

Fig. 12. Comparison of scores on classroom management for both robots.

just the robot's effect on the children.

B. Classroom Assessment of Lessons with Nao robot

The scores for the lessons with Nao robot are shown in Fig. 7 for the classroom atmosphere, and Fig. 8 for the classroom management.

For the classroom atmosphere, the data show relatively positive responses. There is a spike in Lesson 2, which was the lesson about sorting trash. During the lesson, Nao talked about recycling and asked the children to help it sort the trash strewn around it on the floor. Nao walked towards a trash and points to it before asking the children what kind of trash he was pointing to and to which bin should it go. The children would reply by showing Nao a photo of the correct type of bin (for papers, metals, or plastics) and an associated Nao mark. The robot would read the Nao mark to confirm the answer. It was the first time that the children saw that Nao could walk, recognize photos and marks, and point to items of interest.

Similarly, there was a general drop in scores in Lesson 3, which was the lesson on mixing cookie dough. In this lesson, Nao simply read the steps of dough mixing. There was hardly any interaction between the robot and the children. The scores for the appropriateness of the robot for the lesson, for the robot helping in understanding the lesson, and for not experiencing any technical problems from the robot all showed a drop in value. The lack of technical problem was true since the robot did not do anything complicated; it stayed in position and simply read out the dough making steps.

For classroom management, the most noticeable data is the low score for not experiencing any problems (technical or non-technical) during the lesson (see Fig. 8). The problems most often come from the robot itself and commonly include inability to recognize voice input, inability to read visual input (such as when reading markers), slow response to inputs or trigger, disconnection from the router, low battery reserve, motor overheating and the low volume of the speakers. All these problems affect the interaction between the students, teacher, and the robot, which in turn affect the quality of the lesson. The lessons usually recover from these errors by restarting the program or the robot or through the teacher's assistance.

The teacher helps in recovering from the technical issues by managing the expectation of the students. For example, when the robot hangs while processing, the teacher would tell the class that Nao is thinking carefully. Another example is when Nao has to be shut down to cool down its motors or to re-start the program. The teacher manages the class by relating the situation to the children's own experience – that Nao needs some rest because it got tired doing the lesson. This helps keep the children's mood up and increase their patience in waiting for the robot to restart or the problem to get fixed.

C. Classroom Assessment Scores of Lessons with Pepper robot

The compiled scores for the lessons with Pepper robot are shown in Fig. 9 (classroom atmosphere) and Fig. 10 (class management). Similar to the lessons with the Nao robot, the data that stands out for both the classroom atmosphere and the classroom management is about experiencing problem.

The two robots share similar problems such as the inability to recognize voice input, inability to read visual input using the built-in camera and dropping of signal connection to router. Unlike the Nao robot, Pepper does not suffer from battery issues, motor overheating, or low volume of speakers. However, Pepper's built-in tablet becomes an additional source of concern during lessons when used as an input device. When the built-in javascript module is used to control Pepper's tablet, the system slows down considerably and the robot becomes unresponsive. This is remedied by restarting the robot when it happens or by simply using image mapping to accept input from the tablet instead.

The rest of the indicators of both parameters have scores at the positive range (higher than 4).

D. Comparison of the Classroom Assessment Scores

Compared side by side (Fig. 11 and Fig. 12), the two robots have close scores except for the parameter about having or experiencing technical problems.

This difference in score between Pepper and Nao about teachers experiencing problems (technical or otherwise) is very obvious in Fig. 12, Pepper got an average score of 1.50 while Nao got 2.56. The lower score of Pepper could be explained by understanding the design of the robot and the lesson flow.

In the experiments, Nao interacts with the class mostly via its camera and button while Pepper has the tablet as the extra input interface. However, Pepper's tablet is also prone to hanging and not as responsive as a normal tablet. Unfortunately, the tablet was used in all lessons, making this issue an expected feature of every lesson with Pepper. In short, Nao has one less opportunity to suffer technical glitches because it does not have a tablet.

Both the children and the teacher had gotten used to the tablet's unresponsiveness that the children have learned to become more patient and understanding. They would sometimes say that Pepper is thinking or maybe tired. They also learned to wait for Pepper to respond first before attempting to click the tablet again and again.

Technical issues aside, the data indicates that the robots are equally acceptable to be deployed as a teaching aid during lessons. Both robots enable a positive atmosphere, generate interest from the class, and fit well into the lesson design. For Pepper's case, it was able to enhance the lessons (average rating is above 4 in Fig. 11.

As far as classroom management is concerned, the scores are around 4 for both robots (see Fig. 12). This means that teachers were in fact comfortable with using and interacting with the robots and that the schools provided the support, tools, and facilities needed to make the lessons a reality. All in all, despite the technical challenges, the robots in fact helped achieved the the objectives of the lesson.

V. CONCLUSION AND FUTURE WORK

This paper presents the result of a pilot study of deploying humanoid social robots in pre-schools. The main goal of the study is to understand the possible benefits and challenges of deploying the robots in a real class. The two robots, Nao and Pepper, were separately deployed in two kindergartens for the duration of the study. The lessons were observed for individual student behavior and classroom performance, and data were compiled for analysis.

The first learning from this pilot study is the validity of using robot in the classroom regardless of the form or design of the robot. The robots allow the children to exhibit the desired behavior such as using their critical thinking skills and their imagination, and being sociable and independent.

The second is the challenge of using robots in out-of-laboratory setting. The teachers experienced technical issues that, while managed in a variety of ways, could discourage mass-scale adoption. However, it is important to bring these issues to light in order to guide designers, developers, and engineers on what would improve user experience when interacting with robots.

The third is the value of institutional support to make the lessons with robot a reality. Based on this pilot study, it takes considerable resources to deploy robots as teaching aids. These resources include manpower (engineers, content creators, curriculum and pedagogy specialists), facilities (room airconditioning, trolleys, etc), and tools (computers, cameras, etc) and of course, the robot itself.

The last learning we want to emphasize is the importance of enabling the teachers to be confident in handling the robots. The teachers attitude to and basic knowledge of robots would enable him/her to adjust to the different situations (especially technical glitches) that could happen during a lesson. To build this confidence, teacher training is necessary about the basics of using the robot, robot safety, and techniques in incorporating robotics in a lesson.

This pilot study has shown that there are still a lot to learn about the dynamics of deploying robots in classes. Another important gap in current study is the human-robot interaction (HRI) or a one-to-many interaction, as most HRI studies focus on small groups.

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