Pepper Learns Together with Children: Development of an Educational Application

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Abstract— **An educational use of Pepper, a personal robot that was developed by SoftBank Robotics Corp. and Aldebaran Robotics SAS, is described. Applying the two concepts of care-receiving robot (CRR) and total physical response (TPR) into the design of an educational application using Pepper, we offer a scenario in which children learn together with Pepper at their home environments from a human teacher who gives a lesson from a remote classroom. This paper is a case report that explains the developmental process of the application that contains three educational programs that children can select in interacting with Pepper. Feedbacks and knowledge obtained from test trials are also described.**

I. Introduction

It has been suggested that robots could be usefully applied in educational settings. Previous research [1] on the use of robots in education has generally followed two main directions: (I) the use of robots as educational material and (II) the use of robots as educational agents. Both of these applications have attracted considerable attention in recent years. This paper focuses on (II) the use of robots as educational agents. Here, the term "educational agent" refers to both robot teachers, which are designed to provide instructions to students, and robots that are designed to study alongside students and support their learning. To disseminate such educational applications, in addition to basic research conducted at universities and research institutes, it is crucial for researchers to develop specific applications in collaboration with educational organizations and enterprises, and report on these latest developments.

This paper reports on an educational application that was developed for Pepper [2], [3], [4], a new humanoid robot designed and developed by SoftBank Robotics Corp. and Aldebaran Robotics SAS. The educational application was developed in collaboration with the University of Tsukuba, Tryon Co., Ltd., a company focused on the management of online educational and English conversation school projects, and M-SOLUTIONS, Inc. The application was planned and developed based on the concept of Pepper "learning together" with children, and an educational agent that would learn alongside children was designed and implemented. The application was designed to be used by children at around the pre-school age in Japan (around 4–5 years old) to study English at home. To realize the concept of Pepper learning together with children in this context, the application was developed using care-receiving robot (CRR) design methodology [5], [6], which has been recognized as an effective method for designing educational agents, and total physical response (TPR) [7], a widely used language teaching method that we considered to be highly compatible with the application.

After explaining Pepper and the developmental process of the application that contains three educational programs in Sections II–IV, we report on useful feedbacks and knowledge that were obtained from test trials in Section V. Due to the nature of product development, it was difficult to conduct a formal experiment to evaluate the application by sufficient number of public users. However, instead, we conducted a test trial in which ten children experienced the beta version of the application. Also, on September, 2014, we conducted an application demonstration to more than 1,000 visitors (adults) at the 2014 Pepper Tech Festival in Tokyo. These opportunities gave us feedbacks and knowledge that are useful in developing educational robot applications at large, which is reported in Section V.

II. The Personal Robot "Pepper"

On June 5, 2014, SoftBank Mobile Corp. and Aldebaran Robotics SAS launched a personal humanoid robot by the name of "Pepper." [2], [3], [4] Pepper was developed as an emotional robot and is able to communicate on a wide range of issues with humans through its autonomous behavior, speech, and emotional recognition function abilities as well as its smooth motion-generation technology. It is noteworthy that the Pepper project actively seeks to involve creators and developers from all around the world. It aims to collect and store applications, content, and intelligent technology components on a cloud and provides users with a platform linked to these.

Pepper's main specifications, as reported in the press release, are introduced below. Pepper was designed for use with online information acquisition and cloud databases, features that enable users to expand Pepper's functions by installing a new software and various applications called robo-appli (robot applications). A software development kit (SDK) that enables a wide range of functions from simple movement manipulations to high-level customizations using regular development languages is provided. Figure 1 and

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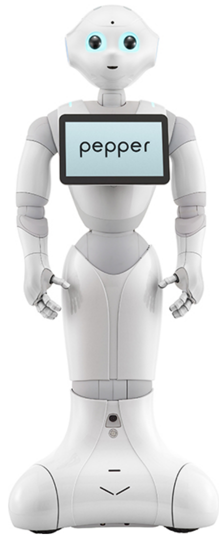

Fig. 1. A personal robot, Pepper.

TABLE I

SPECIFICATIONS.

Size (H x D x W)	1210 x 425 x 485 [mm]
Weight	28kg
Battery	Li-ion 30.0Ah / 795Wh
Sensors (head) Sensors (trunk) Sensors (hand) Sensors (leg)	Mic $\times 4$, RGB camera $\times 2$, 3D sensor $\times 1$, touch sensor $\times 3$ Gyroscope sensor $\times 1$ Touch sensor $\times 2$ Ultrasonic sensor $\times 2$, laser sensor $\times 6$, bumper sensor $\times 3$, gyroscope sensor $\times 1$
DOF	20
Display	10.1 inches touchable display
OS	NAOqi OS
Network	Wireless / wired interfaces
Velocity	Max. 3km / h

Table I show Pepper's external appearance and basic specifications (as planned at the time of the launch).

We utilized the English teaching content for children developed by Tryon Co., Ltd. as well as the company's practical English teaching knowledge to develop an educational application primarily for use at home. In the next section, the design methodology and theory behind the development of the application are explained.

III. CRR AND TPR

A. Care-Receiving Robot (CRR)

As mentioned in Section I, research on robots as educational agents has thrived in recent years and various experiments have begun in Europe, the United States, and Asia [8], [9], [10], [11], [12], [13], [14], [15]. Field studies using Robovie conducted in elementary schools [8] and the childcare robot PaPeRo [16], designed by NEC, are pioneering examples of the use of robots for teaching and caring for children. Subsequently, in Korea, significant progress has been made in the introduction of robot teachers, an initiative wherein venture capital companies are also involved.

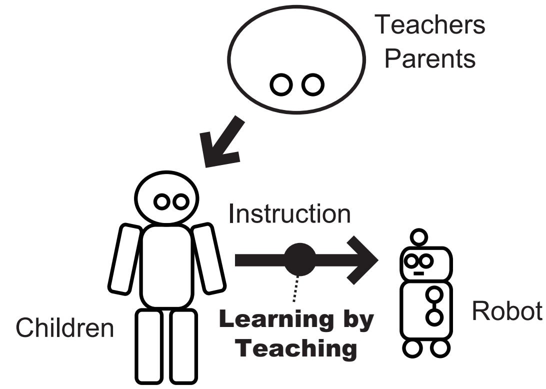

Fig. 2. The concept of care-receiving robot (CRR).[5], [6]

Researchers have also recently begun to establish large-scale projects to develop robotic applications for educating and rehabilitating young children, such as the FP7 Emote and the ALIZ-E projects in Europe and the NSF Socially Assistive Robotics Project in the United States.

In 2009, a new educational robot, designed based on a different concept from robot teachers, was proposed [5]. Prior to this, around 2004, the research group had conducted a long-term field study [17] of the interactions between young children and robots, which found that certain types of robot aroused a strong caring desire in children that continued for a long time without the children getting bored. As a result, the research group began developing robots to "encourage children to teach (or administer care) (Figure 2)." Following these developments, a series of field studies [6] conducted in English conversation schools revealed that this type of robot significantly facilitated children's "learning by teaching." For example, in a lesson wherein young children were learning English verbs, if a peer robot was unable to perform the action "brush" (and performed a different action instead), the children began actively teaching the robot the brushing action by taking its hand and teaching it. Children were intensely focused on the English lesson, and at the end of the lesson, demonstrated the ability to remember and understand the English word "brush." Such robots designed to arouse in humans a wide range of caring behavior have been referred to as care-receiving robots (CRRs). These type of robots have a wide range of applications and have been shown to be useful not only in English language learning but in other educational settings.

B. Total Physical Response

Total physical response (TPR) was a language teaching method developed by Asher in the 1960s [7]. TPR is widely used in classrooms around the world and is often used to teach non-native languages. The key feature of TPR is learning through the coordination of language and physical movement; for example, students have to respond to instructions such as "fly like an airplane!" using whole-body actions (i.e., by raising their arms by their sides and imitating an airplane). Through listening and immediately responding,

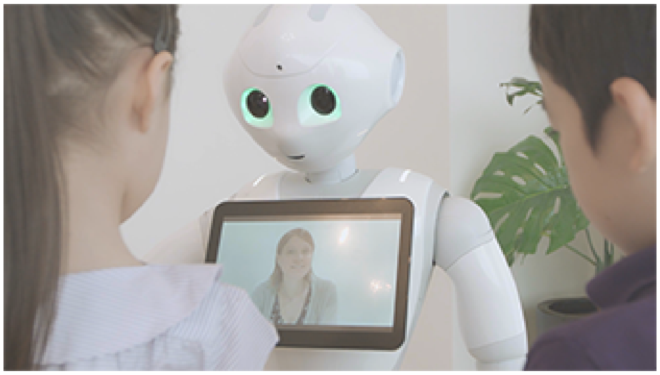

Fig. 3. An English teacher guides a lesson from a Pepper's chest display.

Fig. 4. Children can select a program by touching the display.

students have been found to rapidly recognize the meaning and the linguistic structures of the language being learned. In second language learning, TPR has been used with young children and adults, and has been shown to yield long-term retention levels. In the classroom, one major advantage of TPR is that it enables students to enjoy stress-free learning.

IV. Developing an Educational Application for Pepper Using CRR and TPR

Using Pepper, we developed an educational application for children that incorporated CRR and TPR, the methods have been described in Section III. In this section, the details of this application are explained.

First, the basic concept for the application was that children would "learn together" with Pepper. At the same time, to take advantage of the unique features of the robots, we endeavored to create content that incorporated Pepper's character and physical movements. The application was primarily designed for use at home; hence, we created content for preschool age children to learn English while having fun.

In this setting, a teacher would also be required as Pepper would be a learner with the students. We designed the application for general use in homes and included an English teacher in the lesson who taught through a screen mounted on Pepper's chest. There were two possible ways in which the English teacher could participate, either through a prerecorded video or in real-time from a remote classroom; we decided to use a pre-recorded video (see Figure 3).

In this teacher interaction, we also considered Pepper's reactions so, as shown in Figure 3, Pepper was programmed to look down at the on-screen teacher. Although this was only a minor alteration, it had a significant effect on the actual learning environment and helped create an atmosphere wherein the students, including Pepper, gathered around the on-screen teacher. This aspect was related to human positioning, a method which has been used in various classroom situations including "circle time" and could also contribute to remote learning environments such as home learning.

However, it is extremely difficult to control the direction of the robot's face and this function is not perfect in our application. For example, Figure 4, which is explained in the following section, shows children selecting programs in the application, but in this photograph, Pepper appears to be staring into space. Pepper does have built-in face recognition and tracking functions based on videos captured using a camera; therefore, it is also possible to utilize these functions. However, for example, controlling the on/off switching of the face tracking function (how to time the activation and deactivation of the tracking function) is an extremely sensitive and difficult problem, and effective methods for controlling this function have yet to be developed. We sometimes ruled out the use of the face tracking in the application because we were under the impression that if it contained defects, this function would have the opposite effect to what was intended.

As mentioned above, Figure 4 shows the program selection menu. This time, we developed three programs in the application. These are described below.

A. Color

This program teaches children the names of the colors in English. Figure 5 shows the children using this program. Here, Pepper tells the children, "I want you to teach me red," and says, "Can you show me something red in this room?" Then, the children pick up a red ball (for example) and show it to Pepper (Figure 5, top). When Pepper sees the ball, he says, "Thank you!" and asks the teacher in the chest display, "How do you say *aka* [red] in English?" The teacher in the chest display replies, "We say, *red*," and Pepper and the children repeat the word "red." The program also includes an interaction in which Pepper asks the children, "This is red, isn't it?" confirming what he has learned (Figure 5, bottom). At this point, Pepper plays the role of a CRR, as described in Section III-A.

For this program, we devised a system that made the children active learners. Simply standing still in front of Pepper and looking at the screen throughout the entire activity would cause boredom; hence, to break up the learning activities and to reinforce the learning points, we included actions, such as running to pick up balls in the room and showing these to Pepper, which contributed to the children's enjoyment.

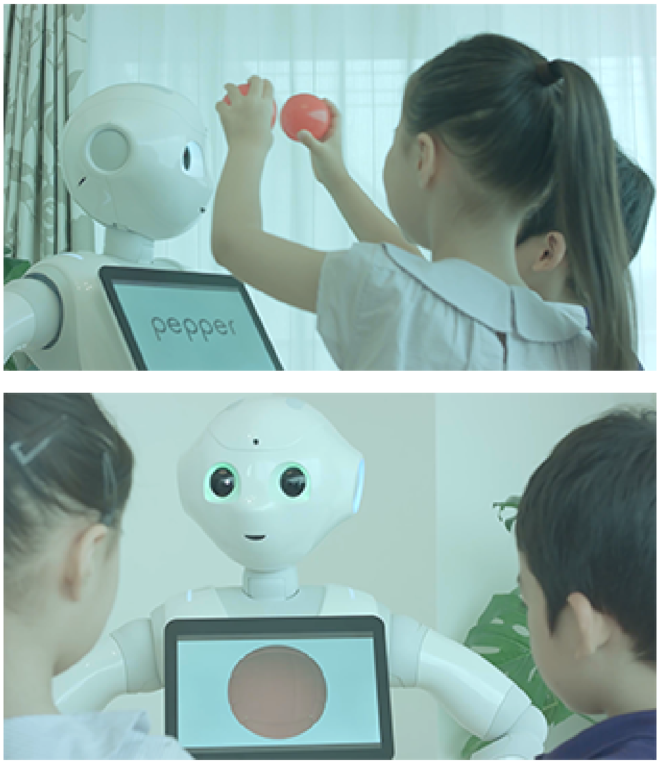

Fig. 5. “Color” game. Children teach Pepper a red color by showing red balls.

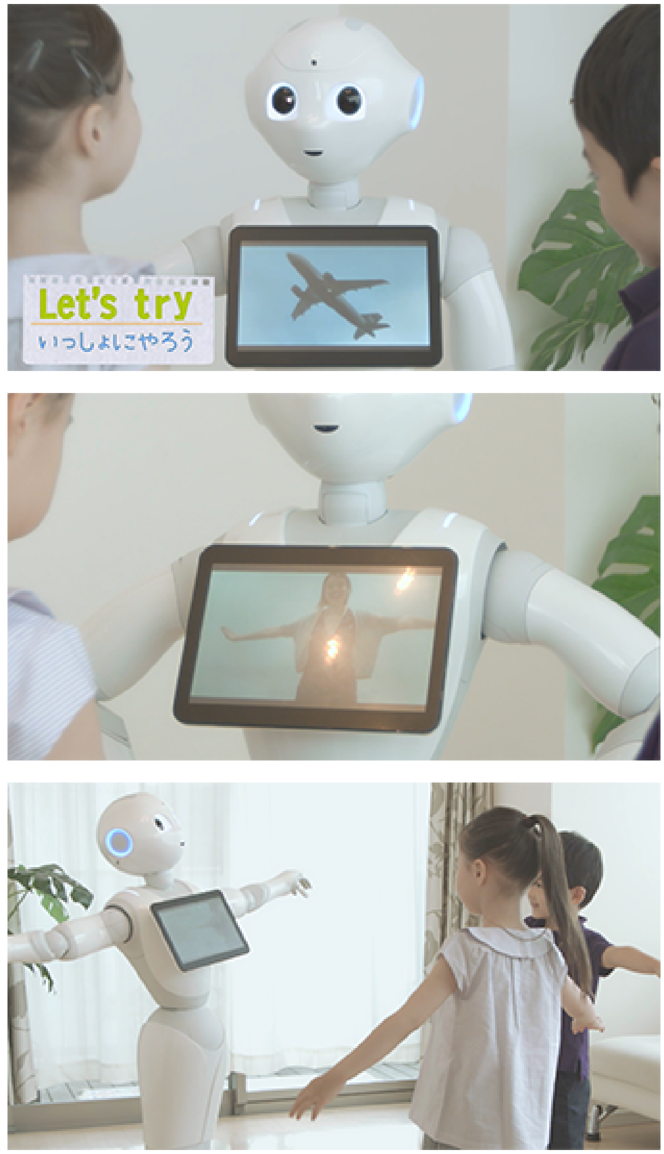

Fig. 6. “Let’s try” game. Children repeat a word ‘plane’ together with a corresponding gesture. This is an instance of a TPR lesson.

B. Let’s Try

This program incorporated TPR, the teaching method described in Section III-B. Figure 6 shows the children using this program. This activity begins with Pepper showing a video of an airplane and asking the children, “How do you say *hikōki* [plane] in English?” (Figure 6, top). Next, the teacher in the chest display raises her arms by her sides, performs a flying gesture and says, “Plane. Fly like a plane!” (Figure 6, center). Then, Pepper says, “Let’s do it together!” and imitates the teacher’s airplane gesture by raising its arms by its sides and repeating, “Plane. Fly like a plane!” (Figure 6, bottom). The important point here is that the children join Pepper in performing the TPR, taking advantage of Pepper’s capacity for physical expression to create a program that compels children to participate.

C. Body

This program incorporated CRR’s concepts and direct teaching to help the students learn English. Figure 7 shows the children using this program. In this activity, the on-screen teacher leads a lesson in which students learn the English words for body parts. As shown in Figure 7, the teacher takes the on-screen Pepper’s hand and teaches it the word “mouth” while placing its hand on its mouth. Next, the in-home Pepper says to the children, “Teach me like that teacher is doing.” Then, the children take Pepper’s hand and teach it the body part. This teaching method is known as “direct teaching,” and according to previous CRR research, promotes children’s learning [6].

In addition to the three programs introduced above, the application also includes several other features. As shown in previous research on human-robot interaction [17], physical contact (i.e., touching) plays an important role in children’s long-term interaction with robots and is thought to be effective in maintaining children’s interest in interaction. Therefore, the application includes “high-five” interactions at various points in the programs (see Figure 8). High-fiving is often used by teachers in regular classrooms and is thought to play a significant role in bonding with children.

We also utilized the function of shooting photos using Pepper’s cameras embedded on its forehead and mouth. For example, taking a photo during an interaction and presenting it to children offered a great reward to them, increasing their further motivation to interact with Pepper.

Fig. 7. "Body" game. Children take Pepper's hand and teach where a 'mouth' is. This is an example of a direct-teaching that is known to be effective for vocabulary learning.

Fig. 8. Haptic interaction such as high five is a key to bond children with robots.

V. Knowledge Obtained from Test Trials

Pepper and its educational application are scheduled to be released in 2015. Due to the nature of product development, it was difficult to conduct a formal experiment to evaluate the application by sufficient number of public users. However, we consider it very valuable to report our findings and knowledge obtained from test trials conducted during the development. For example, we conducted a test in which ten children of around the school entry age (in Japan, children begin the first grade after they turn six) experienced the beta version of the application. The content described in the previous chapter was determined from the feedback obtained from this test. On September, 2014, we also conducted an application demonstration to more than 1,000 visitors (adults) at the 2014 Pepper Tech Festival in Tokyo. In this section, we will summarize the knowledge obtained from these opportunities.

- The aspect that generated the most questions from adult visitors was safety, and while visitors held high expectations for the application, attention inevitably turned to the risks associated with its possible introduction in the home environment. As with all applied robots (and especially in view of the age of the users), safety is an extremely important issue. When Pepper detects humans and objects within its proximity, safety controls are activated using its various sensors. However, these safety controls should be regarded as a work in progress and all possible outcomes still need to be fully explored.

- The application reported in this paper has three standalone programs. However, in the early stages of development, we intended to create a longer scenario to incorporate all three activities within one program as a continuous series of procedures. This time, with the demonstration at the abovementioned Tech Festival in mind, we changed the structure of the application to include three short, 90-s programs that users could select. However, when used at home, we are still unsure as to whether this structure is the most effective. The advantage of the current structure is that each program can be modularized, thus enabling users to flexibly use the applications. While this also has the advantage of enabling the user to select content according to their tastes, it also raises the possibility that the user may quickly become bored with certain content. On the other hand, while longer scenarios could cater for wider educational content, the degree of constraints imposed by the usage environment would be greater. In home use especially, environments vary from home to home. Therefore, it may also be possible to prepare several base patterns for the early introductory stages and then provide content packages tailored to the conditions in each individual home.
- As mentioned in Section IV-C, physical contact such as touching plays an important role in children's interaction with robots, and many parents agreed with the importance. Particularly, there were suggestions as to the use of Pepper's hand to trigger the physical contact. For example, when Pepper opened its hand in front of children, many children touched the hand even if Pepper did not tell them to do so. When developing interactive applications using a personal humanoid robot, designing such cues would become important.
- There observed some cases in which children confused Pepper talking to them with talking to a teacher (in its chest display). Also, when Pepper and the teacher continued a conversation for a long period of time, chil-

dren tended to be left out. These observations suggest the importance of considering a triangular situation and creating a triangular atmosphere in designing interactive applications. For instance, as discussed in Section IV with Figure 3, controlling the direction of the robot's face (as well as its body orientation) is crucial for that purpose. Combining a face-tracking function with proximity sensing is required.

- When Pepper asked questions to children and waited for their answers, it was needed to clarify the ways of answering: verbal answering, touching a button on the chest display, etc. During the beginning phase of the application development, sometimes the ways of children's answering differed from their expected ways by Pepper. In this type of interactions, robots should give clear instructions as to the ways of answering to children.
- Making one-way long conversation from Pepper was unpopular to children. Brief instructions were favored. Monotone speech causes children's boredom; vocal intonation, pitch changes should be taken into account in designing speech contents.
- Keeping eye contact between robot and children seemed to be highly important. The good thing was that thanks to the chest display, children tended to face Pepper most of the time, making face-detection easier. Then, it became practically important to control the on/off of the face-detection/tracking function. In our application, it was programmed by hand along interaction contents. So far it seems difficult to automatize that part, however, this would present an interesting research topic together with the appropriate design of a triangular atmosphere described above.

VI. CONCLUSIONS

This paper reported on the development of an educational application for the personal robot Pepper. Based on the concept of Pepper as an educational agent who learns together with children, we designed application content that utilized Pepper's personality and physical features. Educational content varies widely depending on the target students and the educational setting. Moreover, as children's attention changes from moment to moment, this case is merely the first step towards such an ideal, and in the future, we intend to enhance the application content in terms of both quality and quantity.

One of Pepper's key features is its basic design concept, which can be easily expanded using software, and content collected and stored on the cloud. If Pepper becomes popular at home and users simultaneously become developers and creators, this could result in the creation of a large, diverse, and adaptable IT base, something that could not be achieved through robots and artificial intelligence alone.

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