Development and Utilization of Projector-Robot Service for Children's Dramatic Play Activities based on Augmented Reality

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doi : 10.4156/aiss.vol3.issue5.32

Abstract

With physical actions and digital effects conjoined, Augmented Reality technology generates the "flow effect" (concentration) and encourages motivation. For this reason, there have been recent increases in the number of the studies looking at how AR can be applied to education. Similarly, we deployed a projector-robot at a kindergarten to support AR based dramatic plays by. In order for teachers to easily operate the projector-robot and manage its service, interactive flash-based augmented reality contents have been developed. The significance of the study is in that teachers are able to save time in preparing props for dramatic play classes, while students become more motivated and immersed. The proposed solution is relatively inexpensive and new services are easily added for wide adoption.

Keywords: Robot, Projector, Dramatic Play, Augmented Reality, Robot Service

1. Introduction

Dramatic play is one of the representative activities in enhancing young children's speaking and listening abilities in early childhood education settings [10]. Dramatic play is used to act out literature, stories and scripts, and it includes role playing and modeling [18]. It is more systematic and detailed when dramatic play is created by children themselves and played with spontaneous actions and dialogues constructed from their own imaginations. Dramatic play activity in a kindergarten classroom proceeds by telling or reading children a story, asking them questions about the story content, and helping them take roles, design a stage, act out and discuss the enactment and their reactions [20].

Despite the educational and developmental value of dramatic play, it is not practiced as frequently as expected, other than on special occasions. Provision of the activity includes a dialogue script, a variety of costumes and props, and thus takes a considerable amount of time for a teacher to prepare for it. Today, the real potential for augmented reality (AR) is its capability to help enhance teaching and learning. The 2010 Horizon Report, a joint report by The New Media Consortium and Educause, predicts that augmented reality will be widespread in education within four to five years. The Logical choice appears to be ahead of the curve. While it is easy to see how this AR-infused curriculum would make learning to read more exciting, it also provides the critical learning tools children need to meet the major milestones for reading and learning language arts at kindergarten levels. An issue that may have been keeping AR from emerging in education is that the equipment developed to support the technology was designed for individual use, not for children’s classrooms [13].

IrobiQ is an intelligent robot developed as an educational tool by Yujin Robotics, Inc[22]. Since the November of 2008, when IrobiQ was first commercialized and introduced to Korean preschools and kindergartens on a large scale, its content development has accelerated, reflecting the needs of early childhood education fields. Field research on IrobiQ has been carried out with regards to designing language education programs that are based on picture books and their positive effects on young children's language skills [6], young children's perception of IrobiQ [7,9] and the usage of IrobiQ by young children in a free-play time in a kindergarten classrooms [8].
As Rogers et al. (2002) mentioned, augmented reality with physical action and digital effect combined generates the “flow effect” and motivation, and therefore there has been an increase in the numbers of the cases in which augmented reality technology has been applied to education [20]. However, considering the real situation of the dramatic plays in preschools and kindergartens, it is not a simple task to support dramatic plays activities simply using desktop computers in their classrooms; if robots with mobility and autonomy (self-controlling ability) are utilized, facilitating dramatic play would be more plausible.

Therefore, in this study, in order to accomplish easier accessibility of dramatic plays, AR content are developed captured by projectors mounted on robots, to facilitate Children's dramatic play activities. Additionally, formative evaluation was conducted by applying the service to the actual settings in early childhood education, and analysis was made on children’s understanding of their dramatic play classes (i.e. differences from their conventional dramatic play experiences, points of interest, and the roles of robots).

2. Related Work

2.1. Studies on the Robot-Assisted Classrooms

Palk (October 22, 2010) reported that robots serve a variety of educational purposes and the government is pressing to expand its robot learning, or ‘R-Learning’, programs in South Korea [15]. Han (2010) defined that the R-Learning (robotic earning) mainly consisted of educational service robots, robot assisted learning (RAL) and learning by user-built robots [3]. RAL has seven features: the anthropomorphism of media for learning, autonomous initiation, interaction of teaching and learning activities, greater frequency of virtual as well as physical space and the ability to perform physical activities and display nonverbal messages, a convenient medium of communication for teachers and parents, and encouraging creativity for immersion learning [3].

Most of the recent studies about RAL [4,5,6,7,14] have concentrated on language learning. Studies have targeted mostly pre-school children [7,14]. For example, the research which explores the feasibility of using intellectual robots as a language instruction tool for 4-year olds showed that the children in the robot-assisted groups improved significantly compared with media-assisted groups in certain areas of linguistic ability such as story making, understanding, word recognition and learning vocabulary [7]. This study results also indicated that bi-directional interaction using intellectual robots showed the improvement in students’ linguistic ability.

2.2. Studies on Augmented Reality Robot-Assisted Classrooms

Rogers et al. (2002) categorizes the conceptual space into four transform types, coupling different combinations of actions and effects, in accordance with various physical and digital dimensions. The physical and digital actions with respective effects are common but physical action with digital effect and vice versa are unusual. Augmented reality is another recent change in learning activities [20]. Accordingly, as studies are more and more prevalent on the application of augmented reality to learning, studies on integrating augmented reality to robots and projectors together have been appearing more frequently as well.

First, Ito, Nguyen, and Sugimoto (2008) introduced CENTORO, a system that uses a robot and a handheld projector to support children’s storytelling activities. With GENTORO, children can have a robot playing their own stories in the physical space augmented by mixed-reality technologies. The user study indicated that GENTORO’s features can promote children’s embodied participation, engagement level, and storytelling, and it also helped children with creating and expressing their own original stories [19].

Changa, et al. (2011) designed RoboStage, a system that uses authentic scenes based on mixed-reality technology and robots, and investigated the difference in learning with either physical or virtual characters as well as learning behaviors and performance through the system. The robots in the task were designed to play live interactions among characters. After conducting the study with 36 junior
high students, there was a significant improvement in both conveying a sense of authenticity and increasing motivations, when RoboStage was used [2].

Kwon et al. (2010) and Ahn et al. (2011) created a semi-autonomous remote-controlled projector robot with background projection and control, which generates the synthesized augmented view, camera/movement control, story narration, and various other special effects. Their initial observations lead them to see the future potentials for robots and AR in drawing children’s attention and enhancing the quality of the education [1, 12]. However, they also realized that the methods would require external control, including teachers’ involvement, in order to run the play smoothly without technical interruptions.

3. System Architecture and Development of its Service

3.1. System Architecture

This study pursues to implement a system in which an autonomous projector-robot assists children in the process of dramatic play, while sharing information real-time with outside systems, such as projectors or TVs, allowing spectators to view the content as well. The robot, IrobiQ, uses the following hardware configuration shown in Figure 1 [22]: 1 DoF (Degree of Freedom) arm, 2 DoF head, and a range of emotions expression capability. In addition, the robot also has self-recognition technology for simple images and voices, touch, collision and distance. It has a top speed of 50cm/sec, and can generate voice with English/Korean TTS.

Figure 1. The hardware composition of IrobiQ [22].

As shown in Figure 2, a touch screen and projector are connected to IrobiQ with D-sub cables for dual display support. The ‘Change.Display’ program supplied by Yujin Robot Inc. can also be utilized. However, the projectors focus, resolution and other settings are not supported by the robot’s software platform, and thus still have to be manually adjusted.

Figure 2. Projector-IrobiQ (Left), Dual display (center), and Dual display program (right).
The projector mounted on IrobiQ is small for portability, with dimension of 110×60×26cm, weight of 7Kg, brightness of 30 LUMEN, resolution of 800X600, and projective distance of 0.5m~3.5m. The projector is locked on a stand mounted above the navigation bar in the back of IrobiQ’s head. (See Table 1).

The comparison of IrobiQ projector system in this study with the projector robot system by [1] is as follows in Table 1.

<table>
<thead>
<tr>
<th>Robot system HW</th>
<th>Ahn et al. (2011)</th>
<th>IrobiQ with projector (compact and inexpensive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength &amp; weakness of systems</td>
<td>● simplifying stage settings of dramatic play by utilizing interactive projection backdrop</td>
<td>● possible distribution through existing commercialized robots</td>
</tr>
<tr>
<td></td>
<td>● various advanced camera features including individual close-up by the robot photographer</td>
<td>● flash based augmented reality service that can be applicable to regular computers</td>
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<td></td>
<td>● interactions using props</td>
<td>● increased sense of reality through facial expressions and actions of the robot as well as its mobility in its intervention of dramatic plays</td>
</tr>
<tr>
<td></td>
<td>● narrating interventions and coordinating functions</td>
<td>● possible application of robot’s image/voice recognition and the touch sensor</td>
</tr>
<tr>
<td></td>
<td>● limited facial expressions and actions of the robot</td>
<td>● flash and ROCOS foundation</td>
</tr>
<tr>
<td>Types of dramatic play</td>
<td>● 3 layers (one for stage backdrop, one for augmented reality actors and another for augmented reality characters &amp; props)</td>
<td>● 2 layers (one for augmented reality actors and the other for augmented characters, props and part of backdrops)</td>
</tr>
<tr>
<td></td>
<td>● almost 360 degrees’ of augmented reality with 3D character integration</td>
<td>● 3D marker based 270 degrees of characters</td>
</tr>
<tr>
<td></td>
<td>● interaction with 3D props and backdrops</td>
<td>● 2D flash character service in augmented reality</td>
</tr>
<tr>
<td></td>
<td>● teacher’s coordination</td>
<td>● full coordination by robot or partial coordination by teacher</td>
</tr>
</tbody>
</table>

Compared to the 120 cm sized robot created by [1], IrobiQ is 80cm tall including the projector and its stand, making it easier for teachers to carry around and handle. Above all, since the projector-IrobiQ possesses not only autonomous intelligence but also uses Flash, which is a tool for creating extensive amount of educational contents, teachers can use it very conveniently. Moreover, there is another advantage in that this robot can be readily commercialized due to the infrastructure already established in preschools and kindergartens throughout Korea.

3.2. Development of Projector-Robot Contents

- of Flash based Augmented Reality Contents for the Story of Three Little Pigs
In order to create the augmented contents of projector-IrobiQ, the first steps are as follows in Figure 3 for the story of Three Little Pigs on Flash foundation.

In an effort to create augmented reality content, flash content of Figure 3 is developed in the standardized size of 800x480, after leaving out minimum space for backdrop scenes at the top (sky and clouds) and bottom (fences and flowers) of the screen to provide context for the scenes (Figure. 4. left).

Revision and adjustment was made to the product. To play the content, teachers print out the paper that contain the markers, and then place it in front of a webcam. The computer connected to it will send the imagery from the paper to the screen by reading the coordinates of the marker on the paper, and overlaying a virtual character over the marker in the display screen (Figure 4. right).

A high resolution web-cam of 30,000 pixel was used, an ideal level of resolution that enables long-distance marker detection and also takes into account that the number of interruptions increases as the resolution increases, slowing down the process of the dramatic play.

To support augmented reality technology by using this flash content, the graphics for characters were separated from the props, then, correspondent markers were created respectively as shown in Table 2. This order prevents the graphics of each character and prop from overlapping with each other, even if they appear in the same scene. A test indicated that 8 or less markers are optimum for the execution of a dramatic play. The markers carry 3-D coordinate information; however, this study used the 2-D coordinate information for characters and props.

<table>
<thead>
<tr>
<th>Main characters/ props and their corresponding markers</th>
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<tbody>
<tr>
<td>Characters Props</td>
</tr>
<tr>
<td>The third little pig</td>
</tr>
<tr>
<td>Hay, Ax, Log, Cement, brick, Mama pig</td>
</tr>
</tbody>
</table>
We created our own augmented reality program ‘three-pigs’ by using a library called FLARToolKit, a free, non-commercial applications under the general public license[23]. FLARToolKit is based on NyARToolkit, a Java ported version of ARToolKit that uses a real time video tracking library that calculates the camera position and orientation relatively to physical markers. The FLARToolKit recognizes the marker from the input video and calculates its orientation and position in the 3D world. We have included the helper classes for other major flash 3D engines (Papervision3D, Away3D, Sandy, Alternativa3D) as well [23].

The final version of Augmented Reality based The Three Little Pigs was completed by programming in Flash Action Script 3.0 for the interactions of characters and props overlapped on markers, for example, the sound effect for the ax cutting the log.

- Service of Projector Robot for Augmented Reality Dramatic Play for “Three Little Pigs”.

A robot service executor (RSE) and robot content player (RCP) released from Yujin Robot Inc. are mounted on IrobiQ and designed to play actions and visual contents. To connect the robot’s facial expressions, actions and TTS all together, a robot script has been developed and can be operated by the robot service executor (RSE). Flash augmented reality content is executed by the robot content player (RCP) (See [17] in detail). For IrobiQ Platform to provide computer based AR content, a robot story board can be made with the consideration of IrobiQ’s actions (facial expression and movement) and TTS in the process of a dramatic play. Based on the story board already prepared, robot script can be drawn out. Figure 5 shows the process of drawing out the robot script with ‘Play TTS’ and ‘Move Arms’ module, by using the ‘content script editor (CSE) view’ in ROCOS. The drawn out robot script then is modified into RSML, a robot based XML, and transferred to the robot virtual middleware(RVM) after being executed in RCP. After that, RVM, through the operating system, expresses desired actions and emotions by controlling the robot’s hardware [17].

Because FLARToolKit is not yet supported in RCP, RCP can be operated by running Flash player simultaneously on IrobiQ mounted with the robot script file (RSMS) already developed and augmented reality flash content (SWF). The execution of the augmented reality content of the projector robot is shown in Figure 5. The projector robot tells the children TTS of the dramatic play narration and performs appropriate actions at the same time, providing augmented reality service that places virtual images of objects including characters over the markers detected by its camera. To maintain simultaneity of the two contents, the robot is programmed to perform actions along with ‘Next’ marker shown in Table 2.
4. Utilization of Projector-Robot Service

4.1. Participants and Procedures

The content developed here was presented to 81 children (attending D kindergarten) of ages 7 and 8. To observe the children’s responses to the robot as a content deliverer, the study divided two different groups of children based on the two different delivering media with the same dramatic play content: one with the IrobiQ and the other with a computer and applied the content to the procession of the dramatic play in 4 different small groups (i.e. 22 children of age 6 with a robot, 19 children of age 7 with a robot, 20 children of age 6 with a computer and 20 children of age 7 with a computer) with 4 actors and spectators per group.

Each group spent one hour to run their dramatic play, and before the actual performance, the actors had a rehearsal time as shown in Figure 6 (two top scenes). After all the performances as shown in Figure (two bottom scenes), the children who had been watching were also given the opportunity to experience the “transformation” using augmented reality technology.

As soon as the play was finished, the children were interviewed on how they felt about the play. The one-to-one interviews were carried out by four researchers, and each of them met with a student for the prepared questionnaire. The questionnaire was composed of three questions focusing on the comprehension of the dramatic play activities (i.e. difference from their old play, interesting parts, things that the delivering media (robot and computer) had done). There were no multiple choices in the questionnaire, but questions asking each student to respond as the way they were thinking, with no examples provided. Five minutes were given for each interview.
4.2. Children’s Responses on the Dramatic Plays Experience

In the interviews following the content based dramatic play, children expressed many opinions. For each question, experts in early childhood and elementary education categorized the responses and arranged them in percentages due to many children with various types of opinions.

● Difference in Dramatic Play Experience

Under the category of the question “How is it different compared to the dramatic plays that you have experienced before?” there were 3 different types of responses: response with the focus on 3-D transformation using augmented reality, one on the content delivering media (robot or computer), and the last on other trivial comparison. First, on the 3-D transformation, 44.1% of robot group responded while 42.9% of computer group did, and both group had similar rate of responses. Regardless of the media, a great number of children pointed out 3-D transformation based on augmented reality as the difference from the old dramatic plays. Some examples of the responses of robot group children are as follows.

“It was as if they actually built real houses.” (age 8)
“Friends changed into like real pigs and wolf.” (age 8)
“Last time, I wore a picture mask on my face, but today, just wearing a hat, I completely changed into a pig and a wolf; and the brick house looked different.” (age 7)
“Before, I wore an animal looking mask on my face at that time, but today, I felt like I transformed in real and had a magic show.” (age 7)

Meanwhile, unlike the responses to augmented reality based 3-D transformation, in the responses focusing on media, there were significant differences in percentages between the robot and computer groups. Focusing on the content delivering media (robot or computer), children in the robot group who pointed out the difference from the previous experiences were 55.9% while the ones in computer group were only 5.7%. Some opinions of the robot group children are like followings.

“I liked watching TV through the robot.” (age 8)
“Instead of people doing the play, but today IrobiQ showed it in the screen.” (age 8)
“I was wearing a hat, with that, the robot changed me into a pig and wolf.” (age 8)
“The old one did not have IrobiQ, but this time it did.” (age 7)
“It was different that the robot was talking a lot.” (age 7)

In the responses of trivial comparisons (i.e. the summery of the story, number of actors, existence of music and etc.), there was much difference between the two groups (robot and computer). Focusing trivial comparisons, responses pointing out the difference from the previous dramatic play experience were only 38% of the robot group, compared to the computer group with 68.6%. Some of the opinions of the robot group children are as follows.

“It makes a difference if there is a pig or not, and if the actor’s wearing a costume or not.” (age 8)
“The story ending was different: originally, the wolf goes into the chimney to plunge, but today, it was caught in a net.” (age 8)
“The number of the actors was different.” (age 7)
“Previously, I was wearing a mask with a string. Today I did it wearing a hat.” (age 7)

As we can see, regardless of the delivering media(robot or computer), a great number of children pointed out 3-D transformation applying augmented reality technology as the difference between augmented reality based dramatic play and the previous conventional dramatic play experiences. However, the number of children who pointed out the delivering media, focusing robot or computer, as the difference of the dramatic play experience, was bigger in the robot group than the computer one. The number of children who mentioned trivial differences that were not related to the purpose of the study was bigger in the computer group than the robot one. With all the responses contemplated, it was
found out that most children positively responded to augmented reality based dramatic play activities, but as a medium, the robot led the children more to the media and technology than the computer did.

● Points of interest
  For the question of “What was interesting?” 3 different types of responses were categorized: augmented reality based 3-D transformation, the content delivering media (robot or computer), and the story itself. 91.1% of the children in robot group liked augmented reality based 3-D, compared to 68.6% in computer group. The followings are some examples of the responses from the children of the robot group.

  “I liked the house the pigs built because they looked real.” (age 8)
  “I liked everything; especially I changed into a pig.” (age 8)
  “I liked how my friends looked. The wolf was so cool, and the pigs were so funny.” (age 7)
  “I liked the way we built the houses, and especially, building the straw house was so interesting.” (age 7)

26% of children in the robot-group said that either the robot or the computer as content delivering media were interesting while only 5.7 % in the computer-group did. The followings are some of the examples that the robot-group children responded.

  “IrobiQ talks, and we enjoyed when it was telling us stories.” (age 8)
  “Because IrobiQ speaks, moves and talks, it’s so funny.” (age 8)
  “The robot showed us interesting things with its monitor.” (age 7)

Compared to this, the children who liked things on the story were 5.9% of the robot group, while 37.1% were the computer group. Some examples of the responses from the children in the robot group are like followings.

  “I liked the blowing the house “Huff and Puff” to destroy the houses.” (age 8)
  “It was funny how the first pig blocked the wolf from coming in.” (age 7)

As we have seen above, regarding questions asking what the interesting thing was from the dramatic play experiences, responses pointing out the augmented reality or the content delivering media were more from the robot group than the computer group. Contrastingly, the number of children who mentioned things focused on the story itself, which is not related to the purpose of the study, was relatively small in the robot group while was over 1/3 in the computer group. As a result, when it comes to inducement of motivation, the robot rather than the computer was attracting more interest in the conveying media and technology.

● The role of the media
  Regarding the question of “What did the robot (or computer) do?, the responses from the children are categorized into 4 types focusing on: technical application of augmented reality to assist dramatic play activities, the things that the delivering media (robot or computer) themselves accomplished, the role performed by the robot or computer to support the dramatic play activities and not knowing what the robot or computer did. Fist of all, responses pointing out technical application of the augmented reality because the robot or computer helped friends transform and build houses were 44.1% in the robot group and 54.3% in the computer one. The examples of the responses from the robot-group children are as followings.

  “IrobiQ changed the things that we wore. It helped us build houses with things like bricks.” (age 8)
  “With that, the mask was looking like a wolf.” (age 8)
  “It made the pigs look like real ones.” (age 7)
  “It showed houses and allowed friends to destroy houses, too.” (age 7)
The responses focusing on what the robot or computer themselves did (i.e. speaking, hand waving, mobility and etc.) were 70.6% of the robot group, and 2.9% of the computer group. Some of the exemplary responses from the robot group children are as follows.

“IrobiQ raised its hands, and made sounds.” (age 8)  
“The moving robot was awesome.” (age 8)  
“Talking IrobiQ was cool.” (age 7)  
“It was talking to us, and it was moving, too.” (age 7)

The responses emphasizing on the role of the robot or the computer played in supporting the dramatic play (i.e. showing hooked up with TV, taking pictures, facilitating comfortable performance and etc.) were 64.7% of the robot group, and 37.1% of the computer group. Some of the robot group children’s responses are as follows.

“It did very hard work. It lighted us (actors) and treated us nicely.” (age 8)  
“It was telling us what to do. The robot explained really well. It took pictures and helped me and my friends work very hard.” (age 8)  
“IrobiQ took a video of the play and made a DVD.” (age 8)  
“It showed us pictures on the screens. It was wearing a box, but it showed a different picture. It also showed us building houses and told us stories.” (age 7)  
“It helped us. We could see the scenes of our play on his belly, so we could act it out. It made the pigs look like real pigs.” (age 7)  
“It helped us to play comfortably.” (age 7)  
“IrobiQ showed the play and even the pictures. It was a hard work, but it was talking with us, in English or Korean.” (age 7)

Lastly, the children who said that they did not know what the robot or computer had done were only 2.9% of the robot group, but 14.3% of the computer group.

As shown above, in the dramatic play class, regarding the question on what the robot or computer did, regardless of the delivering media, a great number of children mentioned the robot or computer transforming friends and helping them build and destroy, and thus pointed out the role of the media as helpers with the application of augmented reality technology. However, on the questions of what the delivering media did and how it helped with the dramatic play, the robot group children responded a lot more frequently than the computer group. On the contrary, the number of the children who answered they do not know what the robot or the computer did was more in the computer group than the robot one. This result also proves that when it comes to the children’s understanding the role of the delivering media, the robot, as a conveying medium, helped better understand the role of the media and technology with more emphasis on them than the computer.

5. Discussions and Conclusion

This study has developed a projector robot that supports dramatic play for children in early childhood by applying augmented reality technology. We also performed formative evaluation by applying the service of the projector-robot to the early childhood education field and analyzes children’s comprehension on the contents based dramatic play (i.e. difference from the previous dramatic play experience, points of interest and the role of the media (robot or computer). For this, a projector robot was prepared, by connecting and installing the projector to the already commercialized IrobiQ. Then, after creating the ‘Three Little Pigs’ content by utilizing the flash library of FLARToolKit, the integration was made by executing the robot script for its service.

After using the developed content for the children in early childhood education settings, analysis was made on the children’s comprehension of the dramatic play activity through one-to-one interviews. To observe the children’s responses on the robot as a delivering medium, the dramatic play was
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Advanced in Information Sciences and Service Sciences. Volume 3, Number 5, June 2011

...proceeded in two different groups using the same content: one delivered by the robot and the other by a computer, and the responses from each group were compared. After interviewing, focused on the three different aspects, such as differences from previous dramatic experiences, interesting points in the play activity, and the role of the media (robot or computer), most interviewees positively evaluated the augmented reality based dramatic play activity. Regarding all three of the categories, we concluded that the robot, as a delivering medium, did a better job than a computer when it came to helping children concentrate on the media and technology, peak their interests and understand the roles of the media. Prospective studies will be required of developing flash based augmented library connected to ROCOS for the wide distribution of the projector robots and applying the robots in the dramatic plays to the authentic settings in order to commercialize it with mass production.

6. Acknowledgement
This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2010-32A-B00183).

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