

Constructing a Digital Authentic Learning Playground by a Mixed Reality Platform and a Robot

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Abstract: In this paper, we introduce a learning playground in classroom implementation. Learning Playground is an interactive stage that learning content can be developed into an authentic, task-oriented scenario. Students can acquire knowledge by experiential learning in Learning Playground. Within current technical supports, we apply mixed reality to create a contextual learning platform and place a physical character, a robot, to connect learners and the virtual world. Referring to the experiment, we see learners' motivations, involvement, pleasure and learning effectiveness increase, and they show their strong preference interacting with a robot with social emotions in the learning process.

Keywords: authentic learning, robot, mixed reality, experiential learning, digital learning playground

1. Introduction

Learning can be meaningful and applied in real use in an authentic context [7]. In accordance with Dewey's experiential learning, true learning only occurs in relevant experience [5]. There have been a number of educators who devoted effort to create an atmosphere in which experiences are reflected upon by the learners [6]. Cavazza [3] introduced a real-time interactive storytelling system which is a four-side CAVE-like (CAVE Automatic Virtual Environment) display operated by a PC-cluster [4]. The user can apply multimodal interactions supported by real-time stereoscopic visualization. This system distinctly aims for full immersion in learning. However, creating certain authentic learning environment in classrooms is chiefly concerned with sophisticated equipments and spatial convenience.

Due to the issue mentioned above, is it possible to provide authentic learning with various contexts in classrooms? A simulative setting with virtual objects can yield simulative performance that correlated with real-world tasks from learners [1]. Thanks for current technical supports; we can offer students authentic learning experience by employing mixed reality (MR). In educational MR applications, *Plant System*, developed in Singapore [11], was for students to experience the concepts of seed germination, photosynthesis etc. In this case, this MR module with a wearable display, head-mounted display (HMD), intended a self-operative task without contextual scenario. HITlab designed MagicBook, an MR interface that transports users between reality and virtuality. MagicBook created an immersive environment within a virtual character represented the user and supported multi-scale collaboration. However, the scale of interaction was still limited in terms of mobility of virtual characters and users' sense of collaboration [2].

Perhaps actively engaging learners in authentic settings is also an issue to be improved. Recently, many studies show that physical characters bring more users' enjoyment and engagement than virtual characters [13]. For example, iRobi [8] can

display learning contents in built-in screen and encourage users through audio sound and simple facial expressions. LEGO Mindstorms is a programmable teaching tool for users to design their own robot and create hands-on learning [9]. Mitnik proposed another classic example that reinforces students' kinematic concepts by constructing graphs and illustrating the robots' movements [12]. These educational robots are generally functioned either as an informative presenter or an instructional kit. There is a potential for more engagement and interaction between learners and the robot.

With respect to the strengths and the concerns of the technology showed above, we propose some issues in educational application:

1. How do we construct an immersive environment in classrooms?
2. How do we present encountered scenario with aims of experiential learning?
3. What can a robot do in learning process to engage students more in an authentic environment?

We introduce Learning Playground, a theatrical stage with a robot companion in classroom settings. We adopted MR and created a contextual learning platform for teachers and students to explore knowledge through immersion. The physical character, a robot companion, of the system is aiming to connect learners and the virtual world presented on the stage. Furthermore, the robot was infused with different emotional feedbacks that cater for a higher engagement and involvement, and in result of a better learning effectiveness.

2. System Implementation

Three aspects concerning Learning Playground will be elaborated on this section: constructing Learning Playground, experiential learning in Learning Playground, and the role of robot companion in Learning Playground.

2.1 Constructing Learning Playground

The origin idea of Learning Playground is a theatrical stage: a performance space includes a scene and a stage. Applying this concept to classroom settings, learning content in Learning Playground is designed with a situated scenario; teachers and students can join contextual learning activities with pleasure in the stage.



Figure 1. Learning Playground with students and teacher



Figure 2. Device setting of Learning Playground

A two-screen theatrical stage with two projections, vertical and horizontal, is a main framework of Learning Playground. As Figure 1 shows, the vertical screen presents a situated scene and content-related information such as a background story, tasked events, and, target learning; the horizontal screen is an extension of vertical scene that provides a stage for learning performance. In this system, the teacher can present learning content

within designed situations into the Responsive Stage (the two-screen theatrical stage), and students can immerse task-embedded learning events on the stage with the teacher's assistance.

The main idea of mixed reality supports us to build an authentic learning environment. We add a robot to substitute students to perform tasks on the horizontal screen. The purpose of adding a physical character not only creates involvement and pleasure through the learning process but also avoids a potential great expense of a full immersion (four-side) in classroom settings.

The main device setting consists of two-screen display, two projectors, a PC, a set of tracking equipment, and a robot. The humanoid robot is assembled with LEGO® MINDSTORMS® NXT 2.0 and other LEGO® elements and sensors. In the aspect of tracking control, an infrared ray transmitter is attached to the robot and a webcam on Figure 2 is set to track the infrared ray; and we develop a tracking module to send coordinates of the robot's locations to responsive stage module (Figure 4).

2.2 Experiential learning in Learning Playground

To design meaningful learning activities, we adopt Kolb's experiential learning modal [10] as our core system rationale. The highlights of experiential learning are learner's direct experience and reflections on doing. The developing learning process is four-stage cycle of learning- Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE).

We choose English learning materials and pick "preposition of space" and "color" out of the course units for elementary level. Considering students' context, Hide-and-seek, a well-known children's game, is our situated scenario for students to utilize prepositions and colors in Learning Playground.

At beginning, the teacher plays a short clip of the background story, a Naughty Monkey, Kiwi, on the stage and introduces the task and the learning partner, the robot. Later on, the students are divided into "hiding the monkey" and "seeking the monkey" respectively. Four colored boxes (pink, purple, brown, and gray) are placed in the scene for the hiding group to hide all eight monkeys in; and there are three locations in each box for monkeys to hide in (in, beside, and behind).

During the task, the hiding group gives verbal commands to the platform, for example, saying "two monkeys in the purple box." Then the seeking group is going to find all the monkeys with the robot within certain time span. The group gives verbal commands to the robot such as "go to the brown box." Once the robot reaches the assigned spot, the vertical screen will show the assigned box and three prepositions in it. When the students come up with a decision, apt animation will be played. As we can see, the target knowledge has been transformed into a tool for students to achieve tasks. The students utilize target language in the process (CE) and they gain feedbacks from the vertical screen (RO). For instance, when students say "behind the brown box," and there are monkeys hiding there, the vertical screen will show the animation of a monkey jumping up from back of the box. In the process of task completion, the decision-making from the hiding and seeking group varied with different situations (AC). In order to achieve the task, competing with the other team, students actively find better strategies (AC). Taking turns experiencing hiding and seeking experiences is regarded as a complete set of the learning process in the system. It is thus that students' role in learning process becomes active and dominated in this system.

Figure 3 shows the interactive relationship between the main device and users. The teacher is an editor to blend learning materials into the system and also a coach to ensure smooth running of the activity. The students are task-takers to solve tasks under the robot's

help; the robot serves as the bridge between users and the responsive stage. The robot is also a learning companion to receive missions from students and carry out the missions. The responsive stage is a content agent in charge of presenting related information such as learning knowledge, background story, and descriptions of tasked events. Besides, the stage will also respond to students' decisions to reflect students' comprehension (comprehension checker) by showing apt animation.

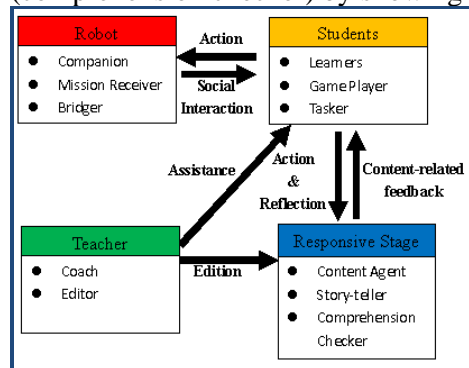


Figure 2. Graph of Learning Relationship

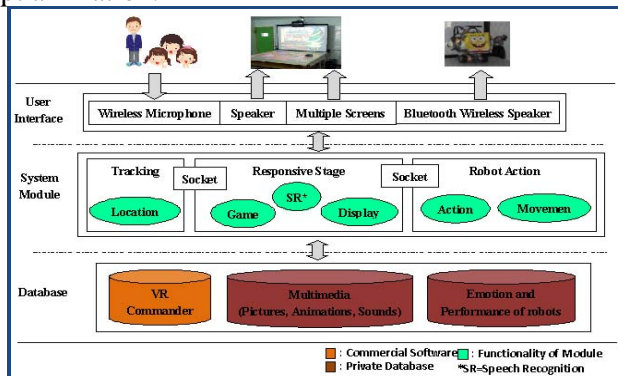


Figure 3. System Architecture

With respect to system architecture, the implementation is composed of three modules, Responsive Stage, Tracking, and Robot Action, as shown in Figure 4. Responsive Stage Module (RSM) demonstrates corresponsive sound, background and visual effects that determined by signal receiving from Tracking Module and meanwhile event signals are sent to Robot Action Module (RAM) for the robot's motions and actions. In terms of amounts of verbal commands, we employ VR Commander as a speech recognition tool in RSM. The results of voice input go to either RAM for mobility or RSM for corresponsive information. Since VR Commander sometimes couldn't recognize the group responses, artificial speech recognition is served as a supportive assistance to ensure a smooth learning process.

2.3 Role of Robot Companion in Learning Playground

For the purpose of eliciting more production, the role of robot, a learning partner, is so as to motivate students conveying and receiving authentic messages. Therefore, social emotions and actions are programmed to develop empathy between users and the robot. The robot can give proper responses with sound effects and simple movements to students. For instance, being idle for certain period, the robot would snore to impel students to give enthusiastic act response. We presume that joining a humanoid robot can enhance motivation, engagement, and involvement, and bring pleasure in the process of learning. The design of robot performance, shown as Table 1, is categorized in three streams: social interactions, emotional behaviors, and learning state:

Table 1. Robot Performance

Act Performance	Expressions	Sound effects and robot behavior
Social Interactions	greeting, praise, and encouragement	Let's get all the monkeys. Excellent! Oops, try again. Turning wrist (behavior)
Emotional Behaviors	happy, hungry, satisfied, and frustrated	Wow, you are awesome. I'm full (hiccup) Circling (behavior)
Learning State	Receiving unclear command, late response, and lack of enthusiasm.	What did you say? I'm lost, please help me. Louder, please. Boring, you ignore me (Snore)

3. Experiment and Discussion

The experiment was held in a classroom with requiring devices. The purpose of the study was to observe learners' behavioral impacts and learning effectiveness through the immersive stage with a robot partner. Questionnaires, progress scores and formative feedback were the means of evaluation data collecting.

3.1 Researching design and hypothesis

We hypothesized that learners could actively acquire and implement target language by using Learning Playground- an responsive two-screen theatre with a robot. The hypotheses through this research were:

1. Utilizing the two-screen responsive theatre with meaningful contexts can enhance immersive experience.
2. Adding a robot companion in learning can facilitate learning motivation, engagement, involvement, and pleasure.
3. Utilizing Learning Playground can fortify learning effectiveness.

To assess the assumptions, learners' behavioral impacts and perspectives through the system were the emphases in this research. Observational data was collected by video-tape recording and user's experiential data was administered by the questionnaires and interview. The objective data related to learning effectiveness was measured by gain scores of the post-test.

3.2 Procedure

This experiment took place in Hua-duo Science & Language Cram School, an after-school academic-enhancing institute, located in Taoyuan, Taiwan. The students are from second to sixth grades. The experiment lasted for three weeks. The main experimental period was about 40 minutes. Each participant needed to take a pre-test and post-test before and after the main activity. The pretest was conducted to understand prerequisite conditions of the students. After completing the pre-test, the participants were randomly assigned to either an experimental or a control group. The number of the control and the experimental group is equally 30. The control group took one English lesson with a teacher. The teacher integrated the target knowledge (color and preposition of space) with the children story, "A color of his own." The experimental group learned target knowledge by immersing in Learning Playground.

3.3 Results and Findings

Users' perceptions and learning behavioral impacts was assembled in two parts: a first section concentrating in the experience toward the Responsive Stage and a second part focusing on the robot with social emotions that was designed for facilitating motivation, engagement, involvement, and pleasure in learning process. We adapt five-point Likert Scale for rating in the questionnaire.

With relation to an overall learning performance within the whole system experience, learning effectiveness was measured by the gain scores of the post-test.

3.3.1 Immersive experience in a contextualized stage in the classroom

The beginning phase was considering whether the interactive contextual cues were relevant to the users. 96.64% of the users perceived the cues from the display and around 83.33% positively stated that they were capable of giving responses. Above 80% expressed they could relate this experience to new daily cases. Approximately 66.7% strongly felt they were playing hide-and-seek with the monkeys. The result demonstrated that the users were highly engaging in the task that was constructed in the immersive setting.

Table 2. Use perceptions and behavioral impacts toward the Responsive Stage (N=30)

No.	Statement	Degree (%)				
		CD	D	Un	A	SA
1	During the course, when I found the monkey with the word "in," I saw the monkey jumping out of the box thus getting the significance of "in the box."	0	0	3.3	33.3	63.3
2	I constantly use the words "in", "beside", and "behind" to accomplish the missions of hiding and seeking for monkeys.	0	0	0	16.7	83.3
3	Due to the constant use of "in, beside, and behind," I've learned, for instance, how to express a ball in the box.	0	0	6.7	13.3	80
4	During the course, monkeys jumping out of the boxes seemed like playing with the animals rather than ordinary English lessons.	0	0	10	23.3	66.7

CD :Completely Disagree; D=:Disagree; UN: Undecided; A: Agree; SA: Strongly Agree

3.3.2 The robot as a collaborative partner in learning

A second part was assessed the effect of a robot with social emotions on motivation, engagement, involvement, and pleasure in learning. Firstly, the awareness of the interaction between the robot and the users reached to 76.7%. 90% showed their preference learning with a robot over sitting in the classroom. 90 % felt having accomplished the mission with the robot partner (engagement) while 86.7% were agreeable they were concentrating in task completion with the robot together (involvement). As to adding pleasure in learning, 76.7% were strongly agreeable that learning with the robot is pleasing.

Table 3. Users' learning behaviors and intentions regarding the robot partner (N=30)

No.	Statement	Degree (%)				
		CD	D	Un	A	SA
1	I perceived the robot had emotions, such as getting tired, feeling helpless, feeling hungry, etc.	0	3.3	6.7	13.3	76.7

2	I get my interaction with the robot. For instance, the robot greets me and encourages me while I let it have candy canes.	0	0	0	23.3	76.7
3	I prefer learning with the robot over sitting in the class.	0	0	10	20	70
4	I look forward to attending courses with robots.	0	0	3.3	23.3	73.3
5	Learning with the responsive scene system, I feel as if actually playing with the monkeys in the settings.	0	3.3	6.7	23.3	66.7
6	I feel having accomplished the mission with the robot.	0	3.3	10	6.7	80
7	As far as I'm concerned, learning with the robot is pleasing.	0	0	0	23.3	76.7
CD :Completely Disagree; D=:Disagree; UN: Undecided; A: Agree; SA: Strongly Agree						

3.4 Results from Objective statistic Related to Learning Effectiveness

For assessing how much the users learned through the device, comparing to the ordinary teaching, the post-test was administered to know their progress. The statistical results were summarized in Table 4.

In order to minimize the influence of the students' prerequisites of the target learning on the experiment, the research treated the pretest as a control variable. An independent two-sample t-test was to analyze the significant difference between both groups. The data ($p=0.675$, $p>0.05$) referred to be non-significant. It indicated that the prerequisites of two groups were similar. The purpose of omitting the variable was met.

Table 4. T-test of pre-test and gain score with control and experimental group.

Test	Groups	N	Mean	Std. Dev.	two-tail t-test			
					<i>F</i>	<i>t</i>	<i>df</i>	<i>Sig.(p)</i>
Pre-test	Control	30	36	25.41	0.646	0.421	58	0.675
	Experimental	30	38.67	23.60				
Gain Score	Control	30	68	20.81	0.558	2.249	58	0.028
Post-test	Experimental	30	80.83	23.33				

We analyzed the gain scores of the post-test in two groups. Applying an independent two-sample t-test to the gain scores, the result can be seen significant differences ($p=0.028$, $p<0.05$). The result highlighted the experimental group learning with the device gained more scores than the control group.

3.5 Discussion

Overall, we can see that Learning Playground successfully conveyed information under an authentic context to the audience and elicited feedbacks from learners.

Through the observation of the experiment, we found the robot played an essential role engaging students. The students showed their strong preference interacting with a robot with social emotions. Particularly when the robot was snoring, the students urged their teammates to make decisions in order to motivate the robot. In one of our experimental days, the robot couldn't function effectively, including lack of responses, and mobility and then the students were upset and impatient through the process.

From the interview about future implementation, some students expected more diversity in Learning Playground which meant to explore different kinds of tasks. Moreover, some students expressed their desire to have more robots for competing with other classmates. Last but not least, the students regarded the device as a learning supplement that positively installed in classrooms.

3.5.1 Limitations

There are some concerns about technical support and future implementation. At first, we assumed natural language would be elicited under an authentic learning. However, the device of the speech recognition couldn't exactly pinpoint students' articulation which met the teacher's expectation or task requirements. The limitation of the speech recognition affected the mobility of the robot and the smooth flow of the learning process. One other issue is that classroom implementation of Learning Playground is still an unknown quantity since Learning Playground is still in a pioneering stage. However, there is a positive potential for future implementation with respect to an uncomplicated interface and common device, such as PCs, projectors, and a webcam.

4. Conclusion

We have seen Learning Playground provides an authentic learning theatre in classrooms for students and the teacher to join in. Learning Playground simulates a microworld for students to acquire knowledge within the elements of challenge, delightfulness, and competitions.

In future research and implementation, we hope for more meaningful exposures that can be performed in Learning Playground. With well-designed themes plus teachers' cooperation, our system can positively be applied to many subjects, i.e. math, geography, social studies, etc.

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