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A case study of teaching probability using augmented reality in secondary school

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Abstract: In this study, we attempt to present a new way for high school students to explore the relations between empirical probability and theoretical probability and build conceptual understandings of probability by the means of Augmented Reality. Two classes of seventh grade students were selected as an experimental class and a control class. Students were assessed by the pretests and posttests handed to students at the beginning and the end of the class respectively. The quantitative analysis showed an improvement of the mean score between the two groups. Also, the qualitative analysis of the open-ended questions and interviews of students and the teacher showed their strong inclinations toward the Augmented Reality technology-equipped instruction.

Keywords: Augmented reality, post-secondary, probability learning

1. Introduction

Augmented Reality (AR), as a branch of Virtual Reality (VR), brings about richer immersive experience than ordinary virtual reality technologies, successfully combining the virtual world and real world. Virtual Reality generally constructs a complete virtual world, in which users are not conscious of the real world around them. Augmented Reality blends the scene of virtual objects with the real world and presents them to users at the same time. AR environments provide users with a seamless interface to connect the real world and the virtual world. An ideal AR-based learning environment helps to vividly demonstrate both the real world which is not accessible to learners and the micro worlds which only exist in learners' imagination by using 3D animation. It provides new possibilities for simulating teaching environments, experiencing teaching processes and promoting teaching interaction through certain teaching approaches, including virtual-real blended, real-time interactive or three-dimensional immersive.

2. Related Works

According to recent studies on teaching and learning statistics, a line of inquiry has focused on how to develop good statistical reasoning and understanding in elementary and secondary mathematics classes. Garfield first investigated difficulties in learning basic concepts in Probability and Statistics in 1988, and then he found that the experience of psychologists, educators, and statisticians alike is that a large proportion of students, even in college, do not understand many of the basic statistical concepts they have studied (Garfield & Ahlgren, 1988). However, most of the research involving technological tools integration in statistics and probability courses has been conducted in college settings rather than at the secondary school level. Among the few studies done at the secondary level, Christensen used Microsoft Excel as a supplement in a high school statistics course. According to Christensen's study conducted at Arlington High School in a Probability and Statistics course for junior and senior level students, the experimental group (the one using EXCEL) outperformed the control group on five of the six teacher-created unit tests and on both of the criterion referenced assessments used by the district (Christensen & Stephens, 2003).

Augmented Reality, which brings about richer immersive experience than ordinary virtual reality technologies for students, can help secondary school students build their conceptual understanding step by step. The work presented by Billinghurst and Du¨nser in 2012 surveyed user studies investigating AR value in both elementary and high school classrooms. They found that both research results and classroom studies of educational AR applications were largely positive, supporting the idea that AR can be a valuable teaching tool at these levels (Billinghurst & Duenser, 2012) .

As Wetzel, Radtke, and Stem suggested that image-based teaching can help students to focus their attention (Wetzel, Radtke, & Stern, 1993), research regarding the application of Augmented Reality in K-12 Mathematics Education in geometry topics has been done actively.

Inspired by the mobile collaborative augmented reality system ‘‘Studierstube’’, Kaufmann developed a system for the improvement of spatial abilities and maximization of transfer of learning using Construct3D, which is a 3D geometric construction tool specifically designed for mathematics and geometry education (Kaufmann & Schmalstieg, 2003). Anecdotal evidence showed that Construct3D was easy to learn, encouraged experimentation with geometric constructions and improved spatial skills.

Notably, research regarding the application of Augmented Reality in K-12 Mathematics Education in Geometry and Functions topics, has been done actively based on the free 3D virtual world created by AR. However, we found that AR can also be used to illustrate abstract mathematical concepts. For instance, in the traditional course illustrating probability, teachers tend to guide students to toss coins to explore the relations between empirical probability and theoretical probability, which is time-consuming and boring. With the development of technology, some teachers may use flash software to simulate tossing coins. However, students have no feeling of doing the experiment in the real environment. If we apply AR in tossing coins, students can be more engaged in this experiment and the data collecting process can be finished in a short time. Therefore, we decided to develop a program of tossing coins to help students explore the relations between empirical probability and theoretical probability with the application of AR.

In the paper, we describe a mobile AR application designed for the teaching of statistics and probability at the secondary school level, which will be illustrated in the next section. Also, we compare and assess the effect of AR and TinkerPlots application used in teaching probability.

3. Methods

3.1 Participants

The participants for this study were the seventh-grade students in a middle school of an urban-rural fringe area. All the students were familiar with the usage of the tablet computers and had similar prior knowledge of the concepts of empirical and theoretical probability. At the beginning, the experimental group had 31 participants and the control group had 28 participants. 6 participants in the experimental group and 3 participants in the control group were removed from the final analysis of the study because of the incomplete responses.

3.2 Research Designs

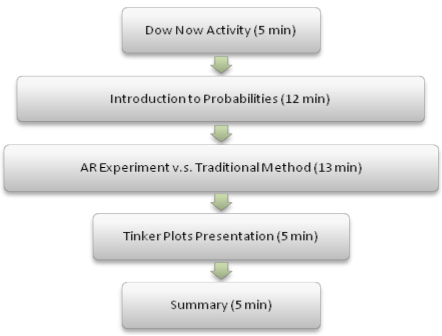

Figure 1. Structure of the Class

The structure of the classes is shown in Figure 1. The first 5 minutes of the class was Do Now activity, a short activity on the board for students to work on as soon as they enter the class and group discussion is allowed in the whole process. In the next 12 minutes of the class, students in both groups were introduced to the basic concepts of empirical probability and theoretical probability separately. The format of this section of the class was a mixture of lecture and group discussion. During the next 13 minutes, the experimental group used the applications in the tablet computers endowed with Augmented Reality technology to explore the relations between empirical and theoretical probability while the control group were using traditional methods, flipping real coins and drawing line graphs by hand. At the moment, group discussions were allowed and students could communicate and seek help from the instructor or the assistant. Following the experiment study was a 5-minute presentation from the instructor in which TinkerPlots was used to show how to generate the relations between empirical probability and theoretical probability on the computer. The last 5-minute instruction was the summary of the class for both groups guided by the instructor.

3.3 Research Tools

In this paper, we implemented a mobile game-magic coins-based on AR on Android OS. The system structure is shown in. Before the start of the first round of the game, users can set two parameters: interval time and recognition time. Interval time refers to the shortest time between two rounds of recognition, and recognition time refers to the shortest time the coin stays in front of the camera. When playing the game, the camera captures the head side or tail side of the coin and the screen will show 3D model in the reality scene in order to prompt the user to a successful identification as shown in Figure 2. Once the recognition is successful, the system will record and update the numbers of head side or tail side as shown in Figure 3. When users exit the game, the historical data will be recorded in the local database for users to access.

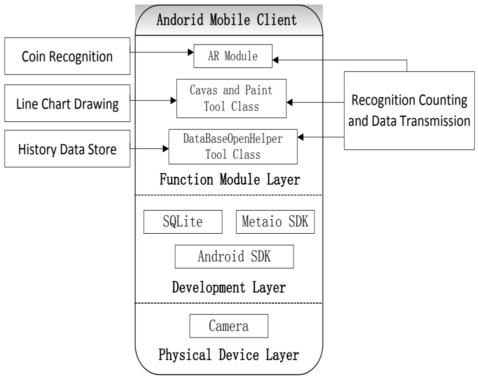

Figure 2. The system structure of the APP

Figure 3. The camera caught the tail side of the coin.

4. Research Findings

4.1 Data Analysis

The main goal of this study was to investigate the influence of Augmented Reality on the secondary school students' learning experience as well as the learning achievements. Pretests and posttests were given to students at the beginning and the end of the class respectively to measure the learning achievements of the students. To be specific, the pretest consisted of ten blank filling questions to assess the participants' prior knowledge of the content area: four of them addressed empirical probability, four of them addressed theoretical probability, and two of them addressed the relations between the two probabilities. The posttest consisted of five blank filling questions to assess the students' learning achievements: one of them addressed empirical probability, two of them addressed theoretical probability, and the rest of them addressed the relationships. In addition, five open-ended questions were also created to determine the AR learning experience of students.

4.2 Pretest Analysis & Posttest Analysis

Table 1shows the independent t-test results of the pretest's scores. No significant difference level in prior knowledge of the content area was found between the students from two groups (t=-0.19, p>0.05).

Table 1: Analysis of the two groups' prior knowledge about empirical probability and theoretical probability.

Group	N	Mean	SD	t
Experimental	25	6.92	0.9539	-0.19
Control	25	7	1.633	

Table 2 indicates the independent t-test results of the posttest's scores. No significant difference level in understanding the content knowledge after the class was found between the students from two groups (t=-0.66, p>0.05).

Table 2: Analysis of the two groups' grasp of knowledge after the class.

Group	N	Mean	SD	t
Experimental	25	4.04	0.7895	-0.66
Control	25	4.2	0.7071	

Besides the analysis of total scores of each student's pretest and posttest, the analysis of the scores of the questions with respect to the relations between empirical probability and theoretical probability were also conducted since the primary goal of the AR technology in the instruction was to clarify the relations between the empirical probability and the theoretical probability.

Table 3 illustrates the independent t-test results of the questions about the relations between empirical probability and theoretical probability in the pretest. No significant difference level in prior knowledge of the relations between empirical probability and theoretical probability was found between the students from two groups (t=-0.2, p>0.05).

Table 3: Analysis of the two groups' prior knowledge about the relations between empirical probability and theoretical probability.

Group	N	Mean	SD	t
Experimental	25	1.56	0.5831	−0. 2
Control	25	1.6	0.866	

Table 4 presents the independent t-test results of the questions about the relations between empirical probability and theoretical probability in the posttest. No significant difference level in comprehending the content knowledge of the relations between empirical probability and theoretical probability was found between the students from two groups (t=-0.3, p>0.05).

Table 4: Analysis of the two groups' grasp of knowledge about the relations between empirical probability and theoretical probability after the class.

Group	N	Mean	SD	t
Experimental	25	1.76	0.4359	0.3
Control	25	1.72	0.4583	

However, it is noteworthy that in the pretest the mean score of students in the experimental group is lower than the mean score of students in the control group. On the other hand, the mean score in the posttest of students in the experimental group is higher than that in the control group as shown in Figure 4. The improvement in apprehending the relations between empirical probability and theoretical probability in the experimental group was to some extent better than that in the control group. The insignificance indicated in the data we collected may be explained by the fact that the class size we experimented on was relatively small.

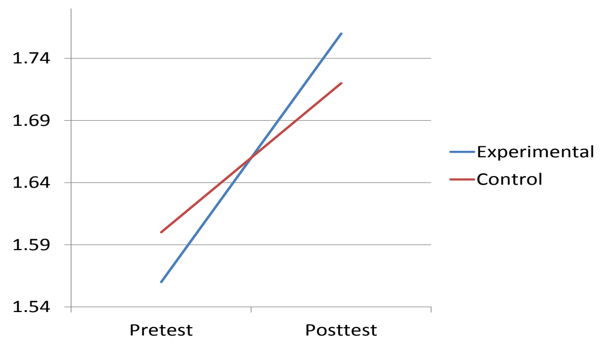

Figure 4. Mean scores of pretest and posttest from two groups.

5. Conclusion

This study was undertaken to investigate the effects of the Augmented Reality techniques on students' learning of mathematics, specifically, secondary school mathematics concentrating on statistics and probability. From the experimental results, it was found that the learning achievements of students by using AR instruction were not statistically different from the outcomes without AR instruction. However, from the qualitative analysis of the AR instruction, both students and the teacher acknowledged the positive influence AR had on students' understanding of the materials. Due to the fact that the sample size is comparatively small, the quantitative result does not show any statistical significance. In future studies, more samples need to be collected in order to further analyze the effects of AR application on students' math learning. Additionally, a real time web server will be created in order to collect all students' data instantly such that students will be able to see a larger sample of data and achieve a better understanding of the material.

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