Using Augmented Reality to Promote Homogeneity in Learning Achievement

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ABSTRACT
The issue of individual differences among learners has thus far received the most attention from education researchers. Many teachers strive to develop a learning strategy with significant effect on the majority of learners. Through literature analysis, this study found that not only could Augmented Reality (AR) improve learning effectiveness, it could also reduce the impact of individual differences on learning outcomes. Therefore, this study designed a set of AR-aided teaching systems to help teachers supplement curriculum content using AR. Sixty-six participants from elementary schools were involved in this study. The results confirmed that AR can help learners to achieve better learning outcomes, and can effectively improve learning achievement in non-high-scoring groups, enabling them to perform closer to those in high-scoring groups and reducing the gap in overall learning level. This study also discovered that technological barriers could reduce the benefits of AR in teaching contexts. Authoring tools with low operating thresholds are valuable for AR-aided teaching systems.

Keywords：Augmented Reality, Computer-assisted instruction, K-12 education

Index Terms：H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; K.3.1 [Computer and Education]: Computer Uses in Education—Computer-assisted instruction (CAI)

1. INTRODUCTION

The application of any learning strategy or tool generates different learning achievements in different learners. A continuous stream of studies have examined individual differences in learners over the past few decades, and individual difference leads to different effects of various teaching strategies on each learner [1][2][3][4][5]. The development of various teaching strategies and technology-aided teaching methods aim to effectively improve achievement in more learners, not confined to outcomes generated by specific or high-achieving learners. Methods for achieving these improvements have been continuously proposed [6][7]. In 1984, Reid proposed a classification method for learning styles; one style facilitated learning through visual images, similar to the viewpoints in the study by Mayer (1987)[7][8]. This learning style, using visual learning methods, may improve the situation encountered by some learners in normal teaching strategies. This provides an opportunity for development of an approach or strategy to help all learners reach positive learning achievements simultaneously.

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Augmented Reality (AR) is a new technology that can effectively improve the achievement of learners in various subjects. The boom of AR technology began in the 1990s, when several researchers started to apply AR to the field of learning, proposing several conceptual practices [9][10]. AR has been successfully applied with differing participants in various fields, including Chinese language, geography and history, mathematical and physical sciences, natural sciences, biomedicine, arts and humanities, entertainment and recreation, advertising and marketing, and so forth [11][12][13][14][15], where it has seen positive results, such as improvements in learning achievement and learning motivation. A large number of studies in recent years have pointed out that AR can significantly improve learning outcomes and promote learning motivation in various teaching subjects and scenarios through the use of additional visual information [16][17][18]. This technology offers new opportunities for visual-type learners, and could be an innovative strategy for helping all learners attain good learning achievements simultaneously.

Analysis of previous studies showed that application of AR technology may lead to greater homogeneity in the achievement performance of learner groups. This study staticized all previous research data applying AR to educational contexts in the Web of Science (SSCI-index) database, and found that, in terms of learning achievement, the participant groups who used AR had an average standard deviation of ($\overline{SD} = 5.93$), significantly lower than that of those who did not use AR ($\overline{SD} = 6.76$) ($t=2.838$, $p=.011<.05$). The above data included empirical data, complete paired comparative data of AR groups and traditional control groups, as well as the standard deviation of participant numbers and learning achievement from quasi-experimental studies. A total of 11 articles met the criteria for selection in our study (Table 1). The samples included a total of 20 groups, with 2039 participants. Among them, 1003 participants received non-AR teaching and 1036 received AR teaching. The calculation method was based on units assigned by groups, and a paired-sample t-test was performed. The included also indicated that students using AR technology performed significantly higher in learning achievement than those aided by other means [17][19][20][21][22][23][24][25]. Therefore, based on the phenomenon of decreased standard deviations, this study hypothesized that AR can work effectively on more types of learners, and enable those with various backgrounds to reach the same standards in learning achievement.

Although these studies have rigorously shown that AR can improve learning achievements, they all illustrate the ability of AR in improving learning achievements from a macro-level and with a holistic perspective, without providing detailed distribution data on individual learning achievements [17][21][24][25][26]. Relying solely on data regarding standard deviations, it is difficult to understand whether AR enables learners at various background levels to reach the same degree of learning achievement, or whether it is possible that the significance of overall performance was

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Table 1. Overview of experimental studies on AR for teaching and learning with empirical data.

Study	N of Other Samples	SD of Other Samples	N of AR Samples	SD of AR Samples
Zhang et al., 2014 [17]	40	4.205	34	4.123
	40	3.948	34	3.403
	40	2.289	34	1.642
	37	4.199	36	3.998
	37	3.985	36	3.578
	37	1.669	36	0.929
Lim et al., 2013 [26]	20	2.01	20	1.42
Ibáñez et al., 2014 [20]	32	1.87	28	1.4
Wei et al., 2015 [21]	16	0.513	17	0.488
	16	0.785	17	0.63
Yang & Liao, 2014 [27]	22	13.6	22	13.7
Chiang et al., 2014 [22]	29	13.703	28	8.763
Jee et al., 2014 [28]	56	18.03	86	18.34
Hsiao 2013 [23]	53	18.596	62	15.505
Liu et al., 2009 [24]	36	9.55	36	7.12
Lim & Lee, 2013 [26]	56	18.03	86	18.34
Civelek, et al., 2014 [25]	109	4.63	106	3.12
	109	4.99	106	4.02
	109	4.11	106	3.64
	109	4.41	106	4.49

derived only from particular types of learners who respond more effectively to AR. Additionally, these studies had different research purposes and complicated experimental designs, and may have included participant groups with variable factors related not only to AR applications, but also to different external variables, such as different teaching fields [17], different forms of information presented [21], and differences in teaching procedures adopted [24][25][26]. Therefore, it is very difficult based solely on these data to make direct inferences on the correlations between reduction of standard deviation and AR. Furthermore, with regard to the application of AR, popularizing the AR system among ordinary teaching scenarios is extremely difficult when using the AR systems discussed in the above-mentioned studies, which, for example, do not provide authoring tools, or require 3D modeling technology [21] or programming capacity [20]. Such factors may lead to difficulty in effectively implementing AR in ordinary teaching scenarios, or in achieving a good quality of implementation.

Considering the aforementioned issues, the specific objectives of this study are as follows:

(1) To facilitate classroom teaching incorporating the use of AR technology, and to analyze whether this technology can effectively improve learning achievement from the perspective of homogeneity in overall achievement; to narrow the gap in achievement standards among learners at various background levels.

(2) To establish an AR system that is coding-free, relatively stable, and rapid; and to develop authoring tools that are easy to operate.

2. METHODOLOGY

2.1 System

A holographic AR engine, the Streamlined Viewport Strategy System (SVSS), developed by Zhang, Hou, and Chang (2012) [29], was adopted in this study as the core of the AR system. This engine was primarily designed to lighten the load generated by algorithms on mobile devices, and to reduce the interference of technological factors in teaching. The SVSS technology has been applied in many indoor and outdoor learning scenarios, and has exhibited its stability and quality [18][30].

This system creates identifiable tags within the content of textbooks (e.g., image or textual paragraphs), and classroom instructors may present supplementary course content via a portable device using AR (Figure 1). The system may utilize original objects to precisely tag particular images, texts, and paragraphs in textbooks, without the need for extra tags (e.g., QR-code, Bar-Code, or AR Toolkit). Thus, classroom instructors can use authoring tools directly to photograph targeted objects for AR. Thereafter, the system will automatically lock onto tags and connect supplementary image-text or multimedia information with a URL. The writing of programming code is not necessary. The specific operational procedures of the system are shown in Figure 2.

Figure 1. SVSS presents additional supplementary materials by way of augmented reality

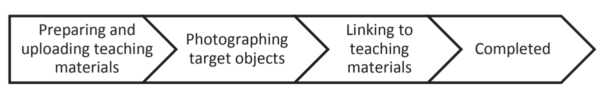

Figure 2. The operating procedures of authoring tools

2.2 Participants

The study recruited a total of 66 participants, aged 11-12 years. Participants were from three classes in an elementary school, namely Class A, Class B, and Class C, with 22, 21, and 23 participants, respectively. Participants in Class A and Class C were 5th grade elementary school students, and those in Class B were 6th grade elementary school students. The participants had the same instructor, an elementary school natural science teacher with 20 years of teaching experience in the subject. Before the experiment, the learning achievements of all participants in natural science were equivalent. According to the calculations based on previous test results, there was no significant difference between the three classes (A,B, t=-.602, p=.551>.05; A,C, t=-.308, p=.760>.05; B,C, t=-.841, p=.406>.05). However, the standard deviations of Class A, Class B, and Class C were 7.135, 6.093 and 9.373, respectively, indicating differences in the distribution of background learning achievement among the three classes.

2.3 Procedure

The experiments were performed using the 5th grade astrological observation module and the 6th grade biology and environment module from the elementary school's natural science department. The entire procedure took 8 weeks. There were 3 classes per week, with each class lasting 40 minutes, for a total of 120 minutes/week. At the end of each course module, a learning achievement test was performed as a post-test, and these test results were regarded as the basis for calculating learning achievement.

When Class A and Class B had lessons, instructors uploaded supporting resources for all the courses, including images, texts, and movies, to the AR system via teacher authoring tools. During class, each student had a Smart Phone, which scanned texts, paragraphs, or images via the camera lens. The teachers' supplementary teaching materials were displayed on the screens of the students' Smart Phones using AR. Class C was presented with identical supplementary course materials using traditional paper handouts and a single-lens projector.

The AR system recorded the total time (unit: minutes) that students spent using the system during the 8-week courses, as well as the frequency of system crashes, system failures, and operating errors caused by students. Because the total time spent using the system involves transfer to the back-end server asynchronously via the Internet, an error value of approximately ±5 minutes may be generated due to technical constraint.

3. Result

After the end of the 8-week courses, the results show that the average length of time spent using the AR system by learners in Class A was 531.14 minutes (SD=34.54), the average score of learning achievements was 91.73 (SD=6.627), and the average number of times in system failures was 0.55. For learners in Class B, the average time spent using the AR system was 351.29 minutes (SD=43.595), the average score of learning achievements was 91 (SD=5.657), and the average number of times in system failures was 0.48. The average score of learning achievements for Class C students was 85.43 (SD=11.657). The learning achievements of Class A and Class B were both significantly higher than that of Class C (A,C, t=2.238, p=.032<.05; B,C, t=2.041, p=.049<.05). However, if only the high-scoring groups (the top 7 high achievers) were taken into account, then the learning achievements of Class A ($\overline{M}$=98.29) and Class B ($\overline{M}$=96.29), when compared with Class C ($\overline{M}$=96), were not significantly different (AC_High, t=1.860, p=.102>.05; BC_High, t=.208, p=.839>.05). Overall, classes that employed AR in teaching had decreased standard deviations in post-test results, lower than those employing traditional teaching methods (Figure 3).

Merging Class A and Class B, if learners were grouped based on whether system failures and crashes occurred while the learners were operating the AR system, 33 participants experienced perfect operation of the AR system without any issues; their standard deviation in learning achievement was 4.294 (pre-SD=6.032). During the 8-week courses, a total of 10 participating learners experienced at least 1 system crash or operating problem. These learners' standard deviation in learning achievement was 7.315 (pre-SD=8.141). This shows that the occurrence of problems with AR systems has an impact on learners' learning achievements (Figure 4).

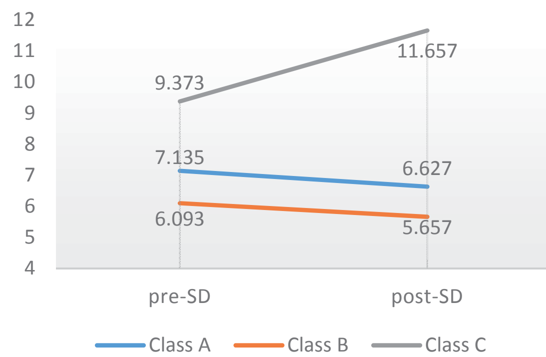

Figure 3.The pre-SD and post-SD value of three groups

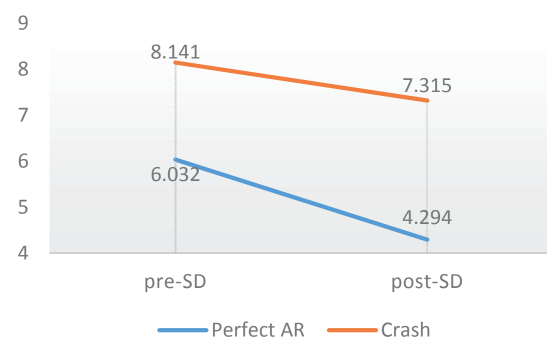

Figure 4. The SD change between perfect AR and who has a system crash or operating problem.

In addition, participants' length of time using AR was compared with their learning achievements, and calculations were performed using the Pearson correlation. The correlation coefficient was 0.322 (p=.035<.05), a moderate correlation, indicating that receiving AR-aided teaching for a longer duration correlated with better performance in learning achievement (Figure 5).

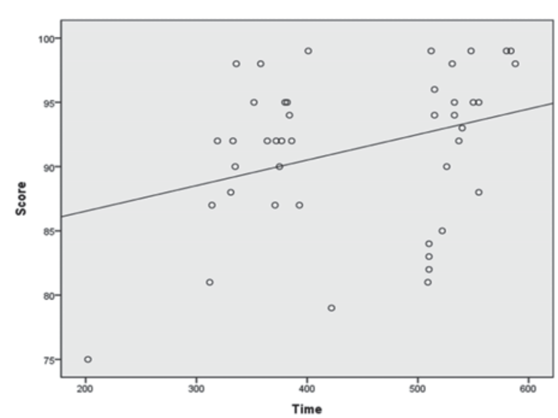

Figure 5. Comparing participants' length of time using AR with their learning achievements.

4. Conclusions

According to the experimental results, the adoption of AR technology to supplement learning materials in the elementary school natural sciences teaching module effectively improved the learning achievements of learners. However, solely in terms of high-scoring groups, learning achievement was not significantly different, which shows that AR technology can effectively improve the learning achievement of learners in non-high-scoring groups. The learning achievements of high-scoring groups may be subject to the impact of how tests are scored, which could generate a ceiling effect (upper limit of scores). Consequently, it is difficult to infer correlation between the performance of high-scoring groups and AR. The reduction in standard deviations of Class A and Class C shows that, compared with traditional learning methods, learners from non-high-scoring groups using AR performed more similarly to high-scoring groups in terms of academic performance. Therefore, the values of overall learning achievement were closer to a state of homogeneity.

According to observations and feedback from instructors after the experiment, the 5th grade astronomical observation module was a more difficult course, relatively. Consequently, the learning achievements of learners was influenced by individual differences, which widened the gaps in test scores between the classes. For example, the degree of acceptance for each learner when receiving materials supplemented by instructors using the traditional methods was significantly different. Some learners were only willing to seriously watch videos played by the teachers, while text-only supplementary handouts might be ignored. The gaps in their levels and understanding were wider compared with learners of the high-scoring groups at the top of the classes. Therefore, the standard deviation of learning achievement significantly increased in the control group receiving instruction by traditional teaching methods. However, when information was presented using AR in Class A, in the same grade and with the same modules, it tended to attract the attention of most learners; consequently, the gaps between each learner in understanding the subject content were narrowed, enabling non-high-scoring learner groups to approach the learning achievements of high-scoring groups. Statistical analysis shows that the standard deviation of learning achievement in Class A was significantly decreased.

Furthermore, data analysis of Class B shows that such phenomena might be applicable to various grades (6th grade) and course modules (biology and environment). Similar phenomena can be observed in the empirical data of many other researchers [17][19][20][21][22][23][24][25].

Through literature analysis, it was discovered from a small portion of research data that several teaching activities using AR led to greater differences in learners' achievements, or insignificant decline in standard deviations [26][27][28]. This study infers that the possible factor could include obstacles in operating technological devices. According to our research results, the learning outcomes of learners who experienced at least one system crash or obstacle during operation were significantly influenced. When compared with learners having a Perfect AR Experience, the changes in standard deviations in learning achievement were less significant. Learners spend a significant amount of time on rebooting the system and surmounting equipment obstacles, which may lead to diversion of attention away from learning objectives. As a result, the meaning of using the AR system is lost.

In addition, based on our data analysis, it was found that the length of time AR was used to facilitate learning was moderately correlated with learning achievement across different ages and disciplines. However, according to observations by instructors, learners who spent a greater amount of time using the system were normally those in the class's medium- to high-scoring groups in class. On the other hand, learners in non-high-scoring groups tended to be impatient in learning; thus, the length of time spent using the system was shorter. However, for learners in non-high-scoring groups, the effectiveness of AR may have considerable appeal. Therefore, the learning achievement ultimately reflected was still significantly superior to that of classes that did not use AR.

With regard to the development of the AR system, as raised in the second research issue above, feedback from instructors indicates that simple authoring tools may strengthen the desire and confidence of instructors in using AR in classroom teaching, particularly coding-free designs, which can reduce difficulty in producing AR-aided course materials.

According to our final analytical conclusion, AR technology plays an effective role in improving the learning achievements of non-high-scoring students. Compared to traditional teaching strategies, the outcome is reflected in the variability of overall learning achievement values. Correlations with gender, background and other multiple factors must be further explored in future studies. Regarding teaching scenarios, this study still suggests using AR for the purposes of assisting teaching, as AR plays a significant role in helping learners in non-high-scoring groups to improve their learning achievements.

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