Deep Motivation or Surface Strategy: Effects of Authentic Technologies on Scientific Learning Outcomes and Study Approaches

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Abstract

The purpose of this study was to investigate the effects of applying two types of authentic technology, the immersion-based augmented reality (AR) and animation simulation (AS), on college students' achievement, study approach, and attitude to learning concepts of natural science. The attention-relevance-confidence-satisfaction (ARCS) model was adopted as a learning framework, and a pretest-posttest quasiexperimental design was employed. In total, 122 college freshmen from three classes participated in the 6-week experimental instruction. The Revised Two-Factor Study Process Questionnaire and an attitude questionnaire were used during the experiment to obtain learners' perceptions and manner of use of these technologies. The results revealed that (a) both types of technology improved knowledge, but the AR group significantly outperformed the AS group; (b) the study approach of the AR group changed from being balanced to being in favor of deep motivation and surface strategy, whereas that of the AS group changed from being balanced to biased toward deep strategy; (c) the AR group had a more positive attitude toward multimedia features and interaction functions, whereas the AS group exhibited a more positive attitude toward teaching materials, interface design, and practicality.

Keywords: Authentic technologies, Immersion-based augmented reality, Simulation-based animation, ARCS model, Natural science

1 Introduction

Next-generation wireless local area network and fifth-generation mobile networks will provide optimal ultrareliable and low-latency communications [1-2]. Therefore, these networks will be tremendously helpful in the field of multimedia teaching and suitable for the construction of a ubiquitous user-friendly mobile learning environment. Current technological transformations in society are bringing new abilities for sensing, adapting, and providing information to users within their environment [3].

Augmented reality (AR) has been applied in various fields, including military training, education, engineering, industrial design, arts, and entertainment [4]. Multimedia computer-assisted instruction increases learning motivation, reduces learning time, and improves learning efficiency. Multimedia enable learners to express themselves, encourage a desire for self-learning, and increase the interaction between instructors and learners. In addition, experiments have demonstrated that obtaining operating experience is vital, and simulation software enables learners to practice [5] without incurring risks involved in conducting physical experiments. Lu and Yao stated that the presentation of abstract material by using multimedia resulted in learners gaining better understanding of the material, and audiovisual displays enabled learners to interact with the material [6]. Courses in which AR is employed boost motivation and result in higher learning achievement [7]. AR creates an authentic learning experience for students without their needing to leave the classroom. The technology can be used effectively and meaningfully in school classrooms in numerous practical ways on the basis of the principles of authentic learning.

Chang et al. [5] reported that the visualization of abstract ideas facilitated learners' understanding by reinforcing the abstract ideas throughout the course, which enabled learners to observe and gain experience within only a limited period. Billinghurst and Henrysson employed AR with learners in both virtual and real environments, and they interacted with virtual objects smoothly; their study suggested novel teaching and learning strategies that can be implemented regardless of learners' prior experience with computers [8]. AR fosters stronger motivation than static images and enables learners to capture the essence of a subject without the limitations of having to read text or view images. The present paper presents a method of employing AR technology to create models for

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teaching on insects. AR is used to reinforce learners' understanding of insects' growth and development. The technology was expected to increase learners' interest and encourage them to learn more about the concepts.

2 Literature Review

2.1 Deep and Surface Approaches

The approach employed by students in the learning process has a crucial effect on the results they achieve from any learning activity. The student approach to learning a conceptual framework [9] divides learning approaches into deep and surface approaches. The deep approach (DA) enables students to relate new opinions to previous knowledge, actively intend to understand the subject, and eagerly interact with the content. By contrast, in the surface approach (SA), students fail to distinguish principles from examples, attempt to learn to repeat what they have learned, and memorize information needed for assessments. This study evaluated the impacts of the DA and SA in the context of AR-assisted learning. Table 1 compares these two types of approaches.

Table 1. Comparison of deep learning with surface learning [10]

Deep learning Takes a broad view	Surface learning Takes a narrow view
Looks for meaning	Relies on rote learning
Focuses on the concepts and arguments to solve the problem	Focuses on the formula to solve the problem
Relates new knowledge to previously learnt knowledge	Focuses on learning unrelated bits of a task
Relates knowledge across modules/courses	Information is memorized solely for assessment
Relates theory to practice	Theory is not reflected upon in real life
Evidence and argument between theories is developed	No cross referencing between theories
Emphasis is student centered	Emphasis is external. i.e. assessment driven

2.2 AR

AR is an extension of virtual reality (VR). Scenes and existing objects are presented virtually in VR applications, whereas in AR applications, information and virtual objects are presented in actual scenes after computations have been made [11]. Real and virtual situations are two ends of a continuum; the possibility of operating with computers categorizes the application environment to establish a theoretical foundation and summarizes the theory. AR learning systems combine virtual materials with a real scene and display virtual materials generated by computers on the basis of learners' ability and self-efficacy. To ensure completeness, AR instructors may add relevant information to the materials. This additional information is beneficial to learners attempting to understand the material [6, 12]. Azuma stated that AR creates a situation that cannot be presented virtually [13]. According to Azuma et al., an AR system has three essential properties:

(1) Virtual objects are combined with the real environment.

(2) Real and virtual objects are aligned.

(3) Real time interactivity is provided.

Some common features—such as immersion, navigation, and interaction—can be derived from Azuma's AR properties [14]. AR can be considered a mixed reality environment that contains more real-world objects than virtual elements [15].

2.3 AR Use in Education

Educators and researchers are enthusiastic about the use of emerging technologies such as AR in teaching and learning [16-19]. Gutiérrez et al. designed an augmented book, titled *AR-Dehaes*, which is considered an easy to use, attractive, and useful material helping students to improve their spatial ability [20]. Nilsson, Johansson, and Jönsson [21] and Liu et al. [22] presented AR systems that support joint planning tasks to improve cooperation between actors from different situations. Several studies have also reported recent AR applications in education and identified the learning affordances of AR. Henderson and Feiner highlighted the unique affordances of AR such as its capacity to promote kinesthetic learning and its support for cognitive memory processes [23]. Chen and Tsai developed an educational AR system on the basis of situated learning theory and applied the innovative interactive technology to enhance library instruction in elementary schools [24]. Di Serio et al. discovered that the positive impact of AR on motivation leads students to be more engaged in learning activities while making less cognitive effort [14]. Liu and Tsai described an exploratory case study regarding the use of AR-based mobile learning material to provide English as a Foreign Language (EFL) learners with enhanced information expression and visual information description and increased information accessibility [22]. On the basis of situated learning theory and by using smartphones, Kamarainen et al. conducted the EcoMOBILE project, which combined AR with the use of environmental probeware during a field trip to a local pond [25]. Zarraonandia, Aedo, Díaz, and Montero stated that the feedback loop between learners and teachers could be improved through the use of AR techniques [26]. Table 2 collates and analyzes education-related AR applications covered in this literature review and identifies AR learning affordances exploited in the literature. The present study analyzes the impact of a basic AR system and

Table 2. Summary of AR applications in education

Research	AR technology employed	Relevant features	Applying course	Learning affordances
Cabero-Almenara et al. [29]	Mobile Devices. HWD.	Immersion. Navigation. Interaction.	Educational Technology. Anatomy. Church of the Annunciation.	Experiential learning. Motivation.
Irwansyah et al. [30]	Unity Game Engine. Android Operating System.	Interaction. Navigation.	Chemistry.	Chemistry especially on molecular geometry.
Faller et al. [31]	HMD. PC. Marker Tracking.	Immersion. Navigation. Interaction	Non-invasive steady-state visual evoked potential	The poles of the slalom.
Gutiérrez et al. [18]	Fiducial markers. PC. Webcam.	Interaction. Navigation.	Mechanical engineering	Spatial ability.
Nilsson et al. [19]	HMD. Marker Tracking.	Immersion. Navigation.	Crisis management	Collaboration.
Henderson and Feiner [21]	Custom-built stereo VST HWD. 10 tracking cameras.	Immersion. Navigation. Interaction.	Military mechanics	Experiential learning. Kinesthetic learning.
Chen, et al. [22]	Fiducial markers. PC. Webcam.	Navigation. Interaction.	Library instruction	Situated learning. Cognitive style learning.
Di Serio, et al. [12]	Markerless images. PC. Webcam.	Immersion. Navigation. Interaction.	Visual art	Experiential learning. Motivation.
Lin., et al. [13]	Fiducial markers. PC. Mobile device.	Immersion. Navigation. Interaction.	Physics	Collaboration. Behavior patterns.
Liu and Tsai [20]	Scenic spot. Mobile device.	Navigation. Interaction.	EFL English composition	Location based services. Meaningful learning.
Kamarainen, et al. [23]	Environmental probeware, Mobile device.	Immersion. Navigation. Interaction.	Ecosystem science	Deeper understanding. Student-centered learning.
Zarraonandia, et al. [24]	Head-mounted AR display. Web application. PC.	Immersion. Interaction.	Computer technologies for the Web	Feedback loop.

then uses monitor-based AR and highly convenient webcams.

3 System Development

3.1 Course Design

According to John Keller's ARCS model of motivation, several methods can be used to supplement motivation in the learning process [27]. ARCS are the four major steps determining whether learners become and remain motivated during the learning process (Table 3). The attention and relevance steps can be considered the backbone of ARCS theory, with the confidence and satisfaction steps relying upon the first two. Attention refers to the interest displayed by learners in the concepts or ideas being taught. Relevance of the process must be established by using language and examples with which the learners are familiar. Confidence focuses on establishing positive expectations of success among learners. The final aspect of the model is satisfaction, indicating that learners must obtain satisfaction or a reward from the learning experience. Feedback and reinforcement are critical elements of learning, and when a learner appreciates the result of learning, they are motivated to learn. Huang, Huang, and Wu employed the ARCS questionnaire to reveal that students who engaged in digital-game-based learning were strongly motivated [28]. This paper focuses on understanding the implementation of the ARCS motivational model in the teaching and learning process, the precise definition of kinesthetic pedagogical practice learning, approaches to its implementation, the advantages and disadvantages of kinesthetic pedagogical practice learning, and finally, implications for teaching and learning experience.

3.2 Implementation

The experiment was performed in two phases and used images, three-dimensional (3D) models, and information related to natural sciences courses. Students were expected to both acquire general information regarding the physical characteristics and movements of insects and learn how to distinguish the

Table 3. ARCS motivational components

Step	Description	Component
Attention	Arouse and sustain a learner's curiosity and interest.	Perceptual Arousal, Inquiry Arousal, Variability
Relevance	Link a learner's needs, interests, and motives.	Goal Orientation, Motive Matching, Familiarity
Confidence	Develop positive expectations for achieving success.	Performance Requirements, Success Opportunities, Personal Control
Satisfaction	Provide reinforcement and reward for learners.	Intrinsic Reinforcement, Extrinsic Rewards, Equity

insects' living environments and maintain their health. To disturb the course to the least degree, the course's design and content were kept intact. The first phase comprised the study of natural sciences and insects by using images illustrating basic knowledge and some relevant information. In the second phase, the iBugs app (Figure 1), designed by Carlton Books Limited, was used to enhance the insect images with information on art details relevant to the course. The material markers were used to superimpose digital data on the images of insects. The number of buttons on the markers was adjusted on the basis of the teaching materials. The buttons were placed at convenient locations, and the button sizes were matched to the standard finger size. In addition, buttons did not overlap other buttons; otherwise, the system would fail to correctly recognize which button was pressed.

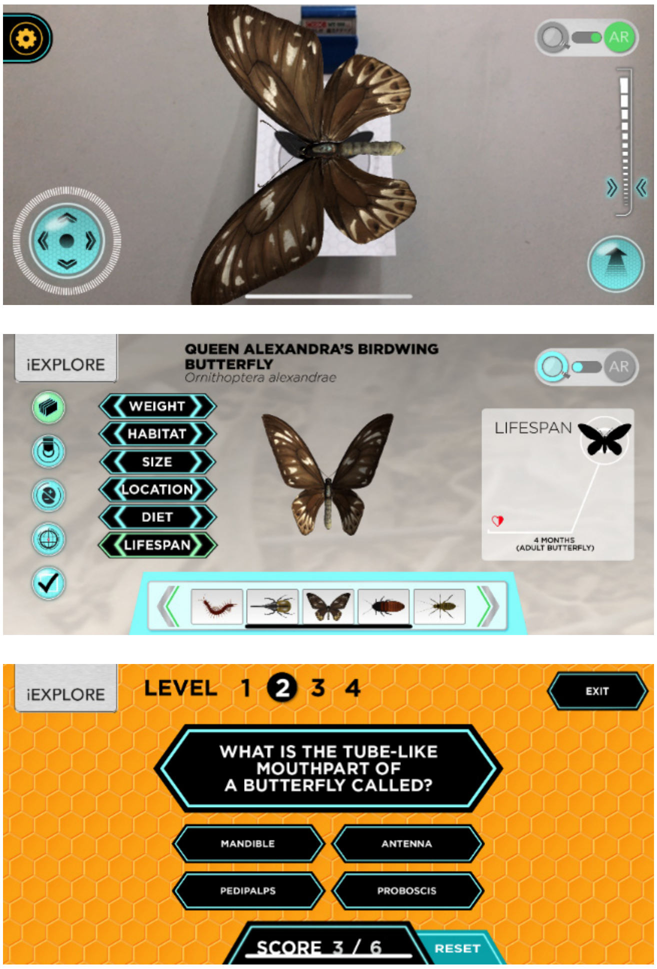


Figure 1. Insect images augmented with information and 3D objects (example of a butterfly)

The added information was multimodal and included text, video files, and 3D models. Students freely explored the AR learning content in a laboratory room equipped with desktops and webcams. By employing AR to show insect growth and development, including use of a zoom function, learners could observe the unique body parts of the insects and learn about the parts' functions and related information.

3.3 System Architecture

This study was conducted in two stages. In the first stage, the AR system and teaching materials were prepared and developed, and in the second stage, a teaching experiment was conducted. Software such as 3ds Max, Maya, Photoshop, and Unity was used to extend the AR system. During the modeling process, the number of surfaces of the model was minimized to ensure rapid computation and execution. Numerous surfaces were required to ensure that the models had similar appearance to insects. Once the models had been completed, a skeletal structure was used to represent the insect anatomy in Maya to simulate the effect of movement. Furthermore, we used Unity and Vuforia to develop the assisting teaching materials. When describing virtual objects, relevant information was presented in the text at the bottom of the monitor for learners' reference. System interactions were designed according to the required functions to satisfy learners' learning and observation needs. Finally, the teaching materials employing AR were presented as web pages and using an Android app. Learners could manipulate the markers on the app to learn. The system design architecture is displayed in Figure 2.

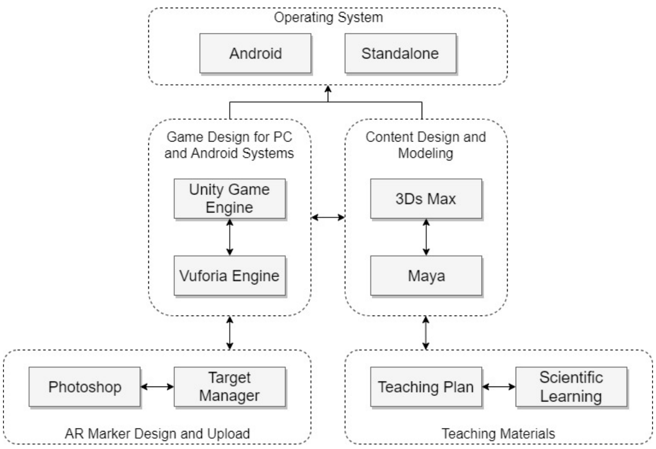


Figure 2. System architecture

The instruction materials developed by this study employed AR for the unit titled “Natural Sciences: Insects.” The materials were used to present the content of the unit. Learners were allowed to manipulate the picture cards to understand the knowledge they contained. Slides were also developed for teaching the unit. These slides were used to teach basic insect knowledge in the classroom. In the traditional simulation group, we used flash animation technology to present the same learning materials as were on the webpage and mobile app.

4 Experiment Design

4.1 Research Method

In the present study, a pretest-posttest quasi-experimental design with an experimental group (AR) and control group (AS) was implemented to investigate the effect of type of authentic technology on college students' learning of insects from an interactive learning activity. Their study approach and attitude toward science learning were also assessed. This study investigated the following questions:

(1) Does any difference exist in natural science learning achievement between students who learned using the immersion-based technology (AR) and those who learned using the simulation-based technology (AS)?

(2) What differences and changes exist in study approaches between AR and AS groups in the acquisition of natural science knowledge?

(3) Does the AR group have a more positive attitude than the AS group to learning about insects through an interactive learning activity?

4.2 Participants

The participants were three classes, a total of 122 students, from a university in Northern Taiwan that offers a natural sciences course in general education. They were randomly assigned to two groups. The AR group, which comprised 63 students (27 women and 36 men), received the immersion-based AR materials (3D objects, related information, and immersion interaction) for learning insect-related scientific concepts, whereas the AS group, comprising 59 students (24 women and 35 men), received the simulation-based materials devised using flash animation technology. The learning content was the same in both the groups. The participants in the two groups were 19.2 years old on average. All the students were taught by the same instructor, who had taught the natural sciences course for more than 11 years.

4.3 Research Tools

The research tools used in this study were learning achievement tests, a questionnaire for measuring student attitude, and the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) for surveying the students' approaches to learning.

The achievement tests were developed on the basis of insect content by three experienced instructors (who had been teaching for more than a decade) in this field. The pretest comprised 20 multiple-choice items designed to evaluate the learners' prior knowledge of the content of the course unit “knowing the insects in Taiwan” before the learning activity. The 20 items were about insects, and 5 points were awarded for each item, resulting in a total of 100 points. The posttest had the same structure and evaluated the learners' ability to distinguish insect characteristics. The posttest assessed knowledge explained in the learning materials of the learning activity, and the perfect score was 100.

The R-SPQ-2F originates from the questionnaire developed by Biggs, Kember, and Leung [32]. It comprises 20 items, 10 of which measure the DA and the other 10 the SA to learning in a classroom or research setting. Within each of these two factors, it was possible to distinguish strategy (the way students go about their study) and motive (the reason students adopt a strategy), which were categorized in subscales into deep motive (DM), deep strategy (DS), surface motive (SM), and surface strategy (SS); each subscale consisted of five items. The questionnaire items were scored using a 5-point Likert scale ranging from “never or only rarely true” (1 points) to “always or almost always true” (5 points). Raw scores were computed by summing the mean score for items identified for each subscale. As mentioned, students that employ a DA might integrate the theoretical and practical components of a course (reflected by DS) with the intention to understand and make sense of the materials (DM). By contrast, students who employ an SA might list and memorize several discrete pieces of information (SS) to reproduce them in the examination and pass the course (SM) [33]. The original Cronbach's alpha values were 0.73 for DA and 0.64 for SA. In this study, the Cronbach's alpha values of the four dimensions were 0.81, 0.83, 0.77, and 0.74, respectively.

The questionnaire assessing learning attitude was based on the technology acceptance model and modified from the measure developed in previous studies [34]; thus, the content validity of the questionnaire was high, enabling careful assessment of the participants' attitude toward our materials. The questionnaire was scored using a 5-point Likert scale ranging from “strongly agree” (5 points) to “strongly disagree” (1 point). It comprised 15 questions on the content of the teaching materials, interface design, multimedia features, interactive functions, and practicality. The internal consistency reliability was assessed by computing Cronbach's alpha, which was found to be 0.89, indicating acceptable reliability.

4.4 Procedure

Before the experiment, the students completed a course on basic natural science, which is a part of the general education curriculum in colleges of Taiwan. The instruction consisted of 6 hours over a period of 3 weeks. For each unit, both the groups completed learning activities that involved reading, videos, field observations, and classroom discussion. At the beginning of the learning activity, the experimental and control groups took the pretest simultaneously and completed the study process questionnaire (R-SPQ-2F). The purpose of the pretest was to discover the degree of equivalence of the two groups in their abilities and readiness.

The experimental group learned using the immersion-based materials developed by this study, which employed AR technology, for the unit "Natural Sciences: Insects." The participants were allowed to manipulate the picture cards (markers) to interact with the 3D virtual objects and acquire knowledge related to them. By contrast, those in the control group learned employing the simulation-based materials developed using flash animation technology to learn scientific concepts through 2D animation and diagrams. The duration of the experimental instruction was 3 weeks. After the learning activity, the students took the achievement posttest, completed the questionnaire of learning attitude, and recompleted the study process questionnaire. All learning activities were video recorded for later observation and further analysis. Figure 3 illustrates the procedure of the experiment.

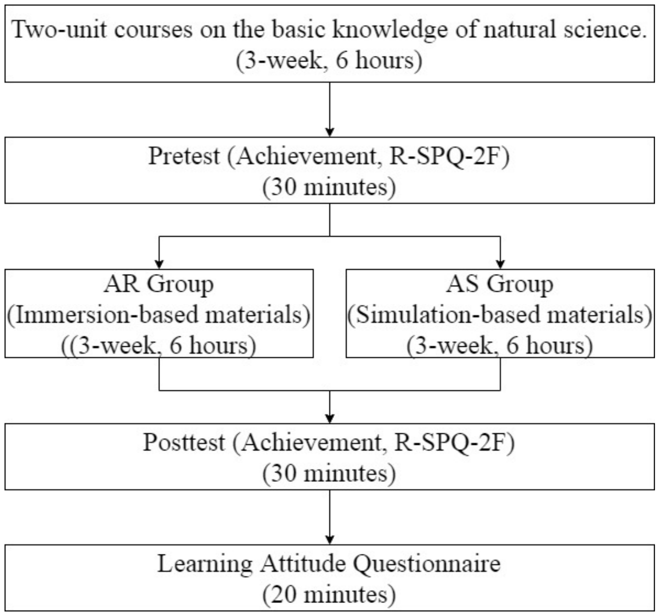


Figure 3. Procedure of the experiment

5 Results and Analysis

One-way analysis of covariance (ANCOVA) was conducted to answer the research questions. The significance level was set at 0.05. The effects of AR on learning performance, study approach, and attitude toward natural science learning are analyzed in the following sections.

5.1 Learning Achievement

The purpose of this study was to examine the effectiveness of different authentic technology types on students' learning achievement. The mean and standard deviation of the pretest and posttest scores of both the groups are shown in Table 4. One-way ANCOVA was employed for the analyses, in which the posttest scores were the dependent variable, the pretest scores were the covariate, and the type of technology was the fixed factor.

Table 4. Mean and standard deviation of scores in the pretest and posttest of learning achievement

Authentic Technologies	N	Pretest		Posttest	
		M	SD	M	SD
Immersion-based (AR)	63	46.81	13.84	79.36	11.83
Simulation-based (AS)	59	47.17	12.67	74.67	13.74

Before applying ANCOVA, the homogeneity of the regression coefficient was tested, which revealed that the interaction $F(1, 120)$ between the covariance was 0.893 ($p > 0.05$). This was nonsignificant and confirmed the hypothesis of homogeneity of the regression coefficient. Table 5 presents the ANCOVA results for the posttest scores comparing the immersion-based (AR) and simulation-based (AS) groups.

Table 5. Descriptive data and ANCOVA results for the posttest of students' achievement

Authentic Technologies		N	Mean	SD	Adjusted Mean	Std. Error	F	p
Post-test	AR	63	79.36	11.83	79.18	1.432	2.537*	0.034*
	AS	59	74.67	13.74	74.89	1.167		

*$p < 0.05$.

According to the ANCOVA results ($F = 2.537$, $p < 0.05$), a significant difference was discovered in learning achievement between the two groups. A further check using the adjusted mean score revealed that the AR group (79.18) scored more highly than the AS group (74.89). Thus, the students who learned using the immersion-based technology demonstrated significantly higher learning achievement than those who learned using the simulation-based technology when exploring insect-related knowledge of natural science.

5.2 Study Approach

Another focus of this study was to explore differences between the groups in terms of transforming the students' study approach. The mean and standard deviation of the pretest and posttest scores of both groups are shown in Table 6. The *t*-tests on the pretest score of four subscales of the R-SPQ-2F revealed *t*-values of −0.042, 0.048, 0.803, and −0.017. All *p* values were greater than 0.05, indicating no significant differences between the two groups. The two groups thus had similar study approaches before the learning activity.

Table 6. Mean and standard deviation of the pretest and posttest scores for study approach

Study Approach	Authentic Technologies	N	Pretest		Posttest	
			M	SD	M	SD
Deep Motive (DM)	Immersion (AR)	63	15.22	1.90	16.62	1.51
	Simulation (AS)	59	15.24	2.05	16.22	1.74
Deep Strategy (DS)	Immersion (AR)	63	15.29	1.45	16.06	2.12
	Simulation (AS)	59	15.27	1.89	16.71	1.65
Surface Motive (SM)	Immersion (AR)	63	14.67	1.41	15.17	1.40
	Simulation (AS)	59	14.47	1.19	14.78	1.43
Surface Strategy (SS)	Immersion (AR)	63	14.81	1.59	15.49	1.41
	Simulation (AS)	59	14.81	1.66	15.14	1.79

Before applying ANCOVA, homogeneity tests were again performed. The regression coefficients of the four subscales—DM (F = 2.09, p = 0.151), DS (F = 0.36, p = 0.550), SM (F = 2.32, p = 0.137), and SS (F = 1.19, p = 0.316)—were calculated. The hypotheses of homogeneity of the regression coefficient were confirmed. Table 7 shows the ANCOVA results for the differences in the posttest scores of the students' study approach between the groups.

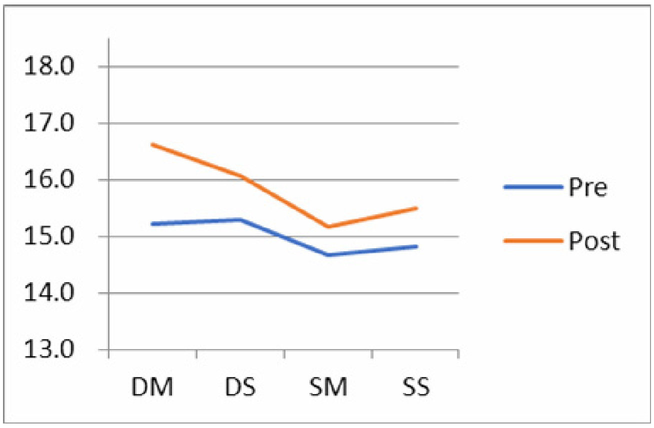
Table 7. Descriptive data and ANCOVA results of the posttest scores for study approach

Study Approach	Authentic Technologies	N	Mean	SD	Adjusted Mean	Std. Error	*F*	*p*
Deep Motive (DM)	Immersion (AR)	63	16.62	1.51	16.63	0.114	6.274	0.014*
	Simulation (AS)	59	16.22	1.74	16.21	0.117		
Deep Strategy (DS)	Immersion (AR)	63	16.06	2.12	16.06	0.235	3.731	0.056
	Simulation (AS)	59	16.71	1.65	16.72	0.243		
Surface Motive (SM)	Immersion (AR)	63	15.17	1.40	15.10	0.108	2.181	0.142
	Simulation (AS)	59	14.78	1.43	14.87	0.112		
Surface Strategy (SS)	Immersion (AR)	63	15.49	1.41	15.49	0.111	5.102	0.026*
	Simulation (AS)	59	15.14	1.79	15.13	0.115		

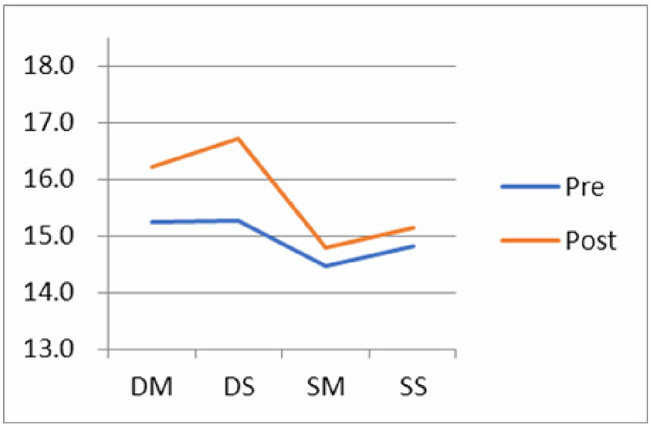
*$p < 0.05$.

Students using a deep study approach might integrate the theoretical and practical components of a course (DS) with the intention to understand and make sense of the materials (DM). According to Table 7, the posttest scores of the two groups were significantly different (F = 6.274, $p < 0.05$). The adjusted mean of the AR group (16.63) was significantly higher than that of the AS group (16.21). However, for the DS, the groups were nonsignificantly different (F = 3.731, $p > 0.05$). Compared with those using the deep study approach, the students employing the SA might list and memorize several discrete pieces of information (SS) to reproduce them in examinations and pass the course (SM). Table 7 shows that no significant differences (F = 2.181, $p > 0.05$) existed between the two groups. However, regarding surface strategy (SS), the posttest scores of the groups were significantly different (F = 5.102, $p < 0.05$); the adjusted mean of the AR group (15.49) was significantly higher than that of the AS group (15.13).

To gain further understanding of the transformation in the participants' study approach, a line chart was drawn (Figure 4). The trends reflected by Figure 4 indicate that the immersion-based technology (Figure 4(a)) raised the posttest scores for all subscales and significantly enhanced the use of DM and SS. As aforementioned, the AR group exhibited significantly greater learning achievement than did the AS group; however, the simulation-based technology (Figure 4(b)) significantly improved the posttest score for the DS subscale, whereas the effect for SA was weaker.



(a) AS



(b) groups

Figure 4. Line charts of four subscales for the AR

5.3 Learning Attitude

In the attitude questionnaire, the participants indicated their feelings and degree of satisfaction regarding the technology they employed in the course. After the learning activity, the participants finished operating the system and completed the attitude questionnaire. Table 8 shows *t*-test results for the attitude questionnaire ratings of the two groups.

Table 8. Descriptive data and *t*-test results of the attitude questionnaire

Dimension	Groups	N	Mean	SD	*t*
Learning materials	Immersion (AR)	63	4.07	0.52	1.04
	Simulation (AS)	59	4.11	0.48	
Interface design	Immersion (AR)	63	4.03	0.61	0.87
	Simulation (AS)	59	4.07	0.57	
Multimedia features	Immersion (AR)	63	4.29	0.66	1.62
	Simulation (AS)	59	4.11	0.52	
Interactive functions	Immersion (AR)	63	4.32	0.71	2.02*
	Simulation (AS)	59	4.14	0.64	
Practicality	Immersion (AR)	63	4.23	0.53	1.16
	Simulation (AS)	59	4.28	0.60	

$^{*}p < 0.05$.

The learners exhibited a positive attitude (mean = 4.38) in five aspects. We discussed with the learners their ideas of the authentic technologies after they had finished the learning activity and completed the attitude questionnaire. The learners agreed that the technologies had increased their interest in the concepts and encouraged them to learn more. The interview data (each interview limited to 15 minutes) were intended to serve as an additional source of information to validate the questionnaire survey. During the analysis, we read through the interview responses, summarized the learners' views, and grouped these summaries to accurately reflect the participants' feelings regarding the AR-assisted learning system.

6 Conclusion

The purpose of this study was to investigate the effects of applying two authentic educational technologies, AR and AS, on college students' achievement, study approach, and attitude in learning regarding insects. The experimental results demonstrated that both technologies improved learning achievement, but AR technology was found to be significantly superior to AS technology. The probable reasons include (1) AR being a new technology; (2) the immersive AR being consistent with flow theory; and (3) AS requiring design by a skilled technician but being only two-dimensional and thus unable to fully render the details of insects.

The study approach in the two groups changed. (1) Overall, in the AR group, the style changed from equal distribution to DM dominant. In the AS group, the style changed from equal distribution to DS dominant. (2) In the AR group, DM and SS were a significant upgrade over AS. However, DM and SS are conflicting concepts.

The students who learned using the AR technology were concluded to have significantly higher deep motivation when exploring knowledge of insects. Interestingly, however, the AR group also exhibited a significant increase in use of the SS in learning activity. The AR-assisted system employed in this research improved not only the students' learning achievement but also their attitude toward science learning. This finding agrees with those of other studies concerning technology-enhanced learning—that effective learning guidance strategies or mechanisms are helpful to students because they improve their learning attitude as well as achievement.

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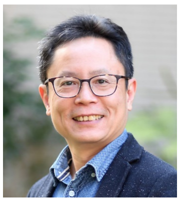
Biographies



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