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A Three-Stage Augmented-Reality-Facilitated Earth Science Instructional Process for Dispersing Learning Style Differences

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Abstract: Studies have proven that merging hands-on and online learning can result in an enhanced learning experience. However, the effects of learning styles have substantially affected online learning performance. As ICT continues to develop, an augmented reality (AR)-embedded instructional orientation could provide additional hands-on experiences to the classroom. In contrast to traditional online learning, multiple in-classroom activities may be involved in an AR-embedded e-learning process, thus could reduce the effects of individual differences. Using a three-stage AR-embedded comprehensive instructional process, an experiment was conducted to investigate the influences of student's learning styles. The results of the study showed that overall learning achievement was significant for the AR-embedded instruction. Nevertheless, as no significant difference found among different learning styles, indicating that our multiple activities oriented AR learning process may have helped disperse the effect of different learning styles.

Keywords: augmented-reality-facilitated learning, learning style, science learning, interactive learning environment

1. Introduction

Some researchers asserted that students learn more effectively with e-learning environments because students like interactive learning that provided by recent interactive technologies (Lee, Choi, & Park, 2009; Hatziapostolou, & I Paraskakis, 2010; Ali Karime, Hossain, A. S. M. M. Rahman, Gueaieb, Alja'am, & El Saddik, 2012). Hrastinski (2009) indicated if learner has an opportunity to control their learning environment, they would have more interest and willing to learn in classes. In an interactive e-learning environment, students would become more positive and active.

Augmented reality (AR) is one of such interactive technologies. It mixes virtual and real world by means of displaying virtual objects onto real images in accordance with target triggers (markers) that manipulating by users. In addition to visualization, users can interact with virtual objects (Chehimi, Coulton, & Edwards, 2007). Many studies revealed that AR systems have educational values because students enjoyed the interaction with virtual objects which is also effective to improve students' learning performance. Among various interactive technologies, interactions with AR were found to be particular helpful for learning spatial concepts (Kaufmann & Schmalstieg, 2003; Kirner, Zorzal & Kirner, 2006; Juan, Beatrice, & Cano, 2008). Researches have also indicated that learning style is important in laying the groundwork for understanding students' learning performance, especially for e-learning, in which learner characteristics is necessarily adapted to the interactive instruction (Huang, Lin, & Huang, 2012). Related works have been done with learning styles in relation to learner's participation, learning quality, and performance of e-learning (Shaw, 2012; Marković & Jovanović, 2011). The results of these researches exhibited there are significant relationship between learning styles and e-learning outcomes in general. Nevertheless, none of these discussions went beyond the realm of traditional online e-learning.

The adaptation of individual differences to e-learning has been discussed for several decades. Johansen and Tennyson asserted that adaptive advisement could help students in perceive knowledge in learner-controlled, computer-based instruction (Johansen & Tennyson, 1993). Magnisalis, Demetriadis, and Karakostas (2011) Claimed that Artificial Intelligence and Web 2.0 techniques could support collaborative learning in an online learning environment. However, all these techniques involve complicated computer algorithm and likely need to comply learning activities within a computer monitor, therefore lack of direct human interactions. Unlike traditional online learning, multiple activities may be involved in an AR-facilitate e-learning process. An AR-facilitate e-learning is able to take place in regular classroom settings, instructional activities may include life lectures, student manipulations of virtual objects, peer discussions, and even written exercises after experiencing the AR. These multiple activities could be more adaptive for learners with different learning styles. However, little research has been done on this issue.

The present study assumed that a comprehensive AR-facilitate learning process consists of various types of learning activities, therefore there will be less effects of learning styles on learners achievements. A quasi-experiment was performed to examine the effects of learning styles on learning achievement while the comprehensive AR- facilitate learning process was given. In the present study, a comprehensive AR-facilitate learning process includes lecture, hands-on AR experience, peer discussions, and written exercises.

2. Related Work

2.1 AR-facilitate Instruction

Azuma (2009) first recognized the AR as a technique that link between the real and virtual world. Yuen, Yaoyuneyong, and Johnson (2011) gave an up-to-date definition to AR. In their definition, AR has three distinctive characteristics: (a) it is the combination of real world and virtual elements, (b) it is interactive in real-time, and (c) it is registered in three dimensions. Thus, AR has some potential to influence instruction and learn knowledge from different fields.

Several researches have used AR systems in education, including mathematics, science, language, and medicine. For example, in their experiment, Kirner, Zorzal and Kirner (2006), a “Game of Word” used plates containing symbols of English alphabets, when setting up a word completed by the plates in front of the webcam, the related virtual object appears over it. They believed that this game was able to motivate the users to interact and create solutions in an attractive AR environment. In addition, Juan, Beatrice and Cano (2008) presented an AR system for learning the interior of the human body. Learners were able to “open” the abdomen of a virtual human body using their own hands. Learners also saw inside the human body virtually, and observed the areas where the stomach and the intestine are located. More recently, Matsutomo, Miyauchi, Noguchi, and Yamashita (2012) created a real-time visualization system, which can visualize a composite image of source materials and their generated magnetic field utilizing the AR technique. They claimed that with such a system, electromagnetics learners can observe the magnetic distribution in a virtual real-time manner.

More AR-facilitate science learning researches have been done in this decade. Recent discussions of instructional applications of AR have gone beyond the effectiveness of the AR per se. For example, in order to better understand the effective strategies that are appropriate for AR-facilitate learning Yoon, Elinich, Wang, Steinmeier, and Tucker (2012) compared four conditions for learning science in a science museum using AR and knowledge-building scaffolds. Results indicated that students demonstrated greater cognitive gains when scaffolds were used. The limitation of above research findings is that they only viewed AR learning as a standalone activity and fall short to vision the entire AR-facilitate learning process, including lecture, peer discussions, and other classroom activities, as a whole. Wang and Chi (2012) demonstrated a comprehensive AR-facilitate learning process, emphasizing in-classroom interactions, to teach fundamental earth science for junior highs. The entire learning process included teacher’s lecture, hands-on AR experiences, peer discussions, and written exercises. They thought that AR-facilitated instruction could improve the understanding of spatial concepts and be easier to acquire the course contents. Nevertheless, the differences between individual students were not discussed in this study. They suggested that further research on individual differences, for example, the learning styles is necessary.

A Synthetic work of AR research was done by Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski (2013). They reviewed recent research on AR learning. They highlighted the potential benefits and limitations of using AR to deliver learning experiences, by presenting an analysis based on psychological constructs, and by comparing AR applications to physical and virtual manipulatives. They concluded that although AR shows great promise for extending the resources used for educating our students, there is much research to be done. Finally they suggested that researchers must more specifically address the usefulness of AR from a psychological perspective.

2.2 Learning Styles

Viewing from the psychological perspective, a line of research has found that learner characteristics had great effects on learning performance. Lamia and Mohamed Tayeb (2013) recognized that learning styles, thinking styles, and levels of knowledge and abilities are key learner characteristic that affects the successfulness of an e-learning. Among these learner characteristics, learning style is an key indicator of how a student learns and likes to learn, and how an instructor teaches to successfully address the needs of the individual students (Chang, Kao, Chu, & Chiu, 2009; Tseng, Chu, Hwang, & Tsai, 2008).

Learning style is a distinctive and habitual manner of acquiring knowledge, skills or attitudes through study or experience while learning preference is favoring of one particular mode of teaching over another (Marković, & Jovanović, 2011). There are a lot of learning style models developed in past fifty years. Witkin, Oltman, Raskin & Karp (1971) first systematically used a Group Embedded Figures Test to identify field independence of the learner. Kolb (1984) employed The Learning Style Inventory as the instrument to classify learner into four categories as convergent learners, divergent learners, assimilators, and accommodators. Keefe (1987) developed a learning style test. It can identify learners into four skill categories: Sequential Processing Skill, Discrimination Skill, Analytic Skill and Spatial Skill. Felder & Silverman’s (1988) model, however, comprises the category of intuitive/sensitive, global/sequential, visual/verbal, inductive/deductive and active/reflective, which can be used to discriminate 32 learning styles. Finally, Fleming defines learning style as “an individual’s characteristics and preferred ways of gathering, organizing, and thinking about information. VARK is in the category of instructional preference because it deals with perceptual modes (Marković, & Jovanović, 2011). The acronym VARK stands for Visual (V), Aural (A), Read/Write (R), and Kinesthetic (K).

Fleming (2012) further explained that life is multimodal. There are seldom instances where one mode is sufficient to describe complicated learner characteristics. For those who do not have a standout mode with one preference score well above other scores resulting from the VARK questionnaire, are defined as multimodal. Therefore he categorized VARK into fifteen learning style within three modes. The three modes are: single mode, dual-mode, and multimode. Fifteen learner styles are then categorized into three modes, they are: V, A, R, and K, for single mode, VA, VR, VK, AR, AK, and RK for dual-mode, finally, VAR, VAK, VRK, ARK, and VARK for multimode.

Huang, Lin, and Huang (2012) criticized that several studies investigated the relationship between learning style and performance most have adopted a dichotomous definition of learning style that does not offer sufficient information for an in-depth investigation of the relationship. The VARK learning style model, however, is among the few that allow categorizes learner into bi/multi-learning style modes. This unique characteristics of VARK classification scheme is particular suitable for the present study.

3. Method

3.1 Research Goal and Questions

The goal of the study was to examine whether a comprehensive AR-facilitate learning process, including lecture, hands-on AR experience, peer discussions, and written exercises, would have extensive adaptions of different learner styles. Based on the assumption that there will be less effects of learning styles on learners achievements while AR-facilitate learning process applied, under the VARK learning style classification scheme, the following research questions were issued:

1. Is there a significant effect of learning style, in terms of single, dual, or multi- mode, on learning achievement while AR-facilitate learning process applied?

2. Is there significant differences among the four single-mode learning styles (V, A, R, and K) on learning achievement while AR-facilitate learning process applied?
3. Is there significant differences among the six dual-mode learning styles (VA, VR, VK, AR, AK, and RK) on learning achievement while AR-facilitate learning process applied?
4. Is there significant differences among the four multi-mode learning styles (VAR, VAK, ARK, and VARK) on learning achievement while AR-facilitate learning process applied?

3.2 The AR Learning Kit

The AR learning kit used for the experiment consists of three components: a sun/earth relation turntable, a computer with screen, and a webcam that captures the birds-eye-view of the turntable. This AR learning kit is able to display a day/night sensitive map and a schematic diagram simulating the changes of pole shadows. The trigger image is the earth on a turntable that simulates the revolution of earth around the sun. There are three images synchronously display on a computer screen. Image on top of the screen displays the overlay images of the earth and the sun. Image on the bottom left side is the day/night sensitive map and image on the bottom right side is the pole shadow schematic diagram. Students are able to turn the earth on the turntable manually and three images will simultaneously simulate the situations in accordance with the date and time displayed on the most top of the screen. Please refer to Figure 1 for the actual orientation of the AR learning kit.

Figure 1. The Orientation of AR Learning Kit.

3.3 Lesson Plan

As AR learning were found to be particular helpful for learning spatial concepts, earth science phenomena: “Day, night, and seasons” that involved spatial orientations of was selected as the learning content. Specific learning objectives were designed as: 1) to understand the interchange of day and night is affected by the earth rotation; 2) to understand the alternation of four seasons is affected by the revolution of the earth; 3) to understand the position and the length of pole shadows are affected by the rotation and revolution of the earth, respectively. Anderson and Krathwohl’s (2001) revision of Bloom's taxonomy of educational objectives was employed as the guideline for constructing the instructional content. Knowledge, understanding, application, and analysis were taken as the four dimensions for instructional content. In knowledge dimension, the phenomena of rotation and revolution of the earth, the interchange of day and night, as well as the move of pole shadow are described and demonstrated. In understanding dimension, the reasons why the phenomena happen are described. In application dimension, students are required to operate the AR learning kit, observe the relationship between the move on the turntable and the coordinate change on AR displays on screen. Finally, in analysis dimension, exercises are provided to allow students use acquired knowledge to analyze given situations and resolve problems.

A three-stage AR instructional process was designed to bring about the learning objectives. The three stages are: gaining attention stage, learning with AR stage, and summarization stage. In the gaining attention stage, the instructor gave lecture on these natural phenomena and showed examples of the relationships between seasons and length of a day as well as the changes of the pole shadows. In the learning with AR stage, students were divided into groups by five, each group operated the AR-learning kit (as shown on graph 1 below). An assistant was assigned to each group to help the operation. These assistants also raised questions after hands-on AR experience for initializing within group peer discussions. Finally, in the summarization stage, students were obtained reinforcements of learned concept. A reflective sheet that required students to answer fill-in-blank questions by operating the AR learning kit was given. A summary of lesson plan for the experiment, including learning activities, amount of time spent, and the learning materials for each stage are shown on table 1.

Table 1: Summary of the Lesson Plan.

Stage	Learning activities	Time	Material
Gaining attention	Instructor gives lecture and shows examples,	25 min.	PowerPoint briefings
Learning with AR	Students operate the AR-learning kit in groups. Peer discussions	50 min.	AR learning kit
Summarization	Students obtain reinforcement of learned concepts	15 min.	Reflective sheet (written form)

3.4 The Instrument

Fleming's VARK learning style questionnaire employed to classify the multiple-tendency of learning styles [www.business.vark-learn.com]. The Younger Version revised on September, 2007 was used to fit the age range (13-15 years old) of our subjects. They are totally 16 questions in the questionnaire. Four selections of possible answers are available for each question. Each answer refers to one of the VARK category. Multiple selections of these answers are allowed. Totally 15 categories can be classified by this questionnaire. The reliability of the Chinese version of the questionnaire is Cronbach's α= .83.

A pretest and a posttest for evaluating the learning achievement were constructed. The revised taxonomy aforementioned was taken as the guideline for constructing test items. Both pretest and posttest have 18 single-answer multiple choice questions. The knowledge and understanding dimensions have four questions, and application and analysis dimensions have 5 questions. The pretest and posttest are designed as parallel forms. The reliability of the pretest and posttest are α= .74 and .84, respectively.

3.5 The Experiment

The experiment was done in two separate junior high schools in New Taipei City of Taiwan in a period of three months. Totally 144 students in five seven-grade classes were selected as subjects. One instructor and seven teaching assistances were involved in the instructional process. An independent three-stage AR instructional process was performed for each of the five classes. A pretest was given before, and a posttest was given after each instructional process was performed. Several students were randomly asked for a brief interview to understand student's interests and motivations on using the AR learning kit.

4. Results and Discussions

4.1 The Distribution of Learning Styles

According to Fleming's VARK classification scheme, students were categorized into 15 learning styles within single, dual, and multiple learning modes. The most prevalent learning style type was "VARK". 35 out of 144 students fell into this category. "V" and "VK" were the two categories that had least students fit in. In terms of learning style mode, most students had multi-modal learning style (80), and least students were single-modal (26). Detailed information please refer to Table 2.

Table 2: Distribution of Learning Mode and Learning Style.

Learning Mode	Learning Style	Number of Samples	
Single-modal	V	2	26
	A	11	
	R	4	

	K	9	
Dual-modal	VA	10	38
	VR	3	
	VK	2	
	AR	9	
	AK	11	
	RK	3	
Multi-modal	VAR	19	80
	VAK	15	
	VRK	4	
	ARK	7	
	VARK	35	
		144	144

4.2 The Effects of Learning Style Mode

The effects of the three modes of learning style: single, dual, and multiple modes on learning achievement were statistically analyzed. An ANCOVA was performed to examine the significance of the mean differences among the three modes. Pretest score was used as the covariance. The result indicated that there was no significant difference on learning achievement found among these three modes ($F_{2,140}$= .017, p=.983). As we also found that there is a significant pretest-posttest gains (t_{286}=10.346, p<.001), it was evident that the three-stage AR-facilitate learning process was adaptive for learners with any learning mode. Table 2 summarizes the ANCOVA.

Table 3: Summary of ANCOVA for Learning Style Mode.

Source	**SS**	**df**	**MS**	***F***	***η²***	***p***
Mode	.327	2	.163	.017	.000	.983
Error	1336.534	140	9.547			

4.3 The Effects of Learning Styles On Achievement

We further examined the effects of learning style types on student's learning achievement. Three separate ANCOVA was performed for the three learning style modes.

There are four types of single-modal learning styles: "V", "A", "R", and "K". The result of ANCONA indicated a near significant result ($F_{3,21}$ =2.581, p=.081). In order to avoid possible type II error, LSD post hoc comparisons was done. The result of the post hoc analyses indicated that the achievement for "R" type learners was significantly better than "A" type (p=.030) and "K" type (p=.012). This result seems to be incoherent with Fleming's account that "R" type of learner prefers to use text-based materials. The possible reason is that the summarization stage helped more for "R" type of students in reviewing the concepts learned during the AR operation. Table 3 summarizes the ANCOVA and the LSD comparisons for the single-modal learning styles.

Table 4: Summary of ANCOVA and Post Hoc For Single-Modal Styles.

Source	**df**	***F***	***η²***	***p***	**Post hoc**
Learning style	3	2.581	.269	.081	R > A, R > K
Error	21				

The differences among six types of dual-modal learning styles: "VA", "VR", "VK", "AR", "AK", and "RK". The result of ANCOVA showed a non-significant result ($F_{5,31}$=1.000, p=.434), there was no differences on learning achievement regarding dual-modal learning styles. Table 4 summarizes the ANCOVA for the dual-modal learning styles.

Table 5: Summary of ANCOVA for Dual-Modal Styles.

Source	SS	df	MS	*F*	η^2	*p*
Style	44.383	5	8.877	1.000	.139	.434
Error	275.140	31	8.875			

Finally, we examined the effects of multi-modal learning styles. Again, the result of ANCOVA exhibited that was no significant difference among "VAR", "VAK", "VRK" "ARK", and "VARK" types of learners. Table 5 summarizes the ANCOVA for the multi-modal learning styles.

Table 6: Summary of ANCOVA for Dual-Modal Styles.

Source	SS	df	MS	*F*	η^2	*p*
Style	85.252	4	21.313	1.858	.074	.127
Error	860.298	75	11.471			

5. Conclusion

An adaptive education combines the development of an individual's initial competence with alternative environments matched to different styles of learning. The Adaptation of individual differences to e-learning has been discussed for decades. However, most efforts have been made to develop intelligent programs to select appropriate instructional paths and/or to determine the amount of instruction to be given based on individual learner's on-task performance. To avoid complicated adaptive computer algorithms, we developed a comprehensive AR-facilitate e-learning process that is able to take place in regular classroom settings. Instructional activities included life lectures, student manipulations of virtual objects, peer discussions, and written exercises. An experiment employing the AR process was done with an earth science learning unit. The VARK learning style classification scheme was used. The results showed there was no significant difference in learning achievement of students with different mode of learning styles.

This result is promising. The present study provides an alternative rationale for developing adaptive e-learning without involving complicated adaptive algorithm. A comprehensive AR-facilitate e-learning process could make the regular classroom to be more adaptive to students with different learning styles.

Although findings of this study are potentially supporting the development of an alternative ICT-based e-learning strategy, some inherent limitations must be addressed. As we admitted the non-significant results related to the differences among learning styles, there were some risks of gaining type II errors. Although most of the non-significant decisions were made on a reasonably reliable basis ($p > .3$), sparse significant results were found in post hoc analyses of single-modal learning styles (R > A, R > K). Another limitation of the study is that the generalizability of the research findings is restrained because only a single learning unit within a single subject matter was implemented for the experiment. For future studies, we suggested that larger sample sizes and extensive subject matters need to be concerned.

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