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Creative Situated Augmented Reality Learning for Astronomy Curricula

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ABSTRACT: Many elementary school students find astronomical knowledge difficult to attain. Students cannot observe planetary motion in the universe, which makes the construction of astronomical knowledge abstract and incomprehensible for many students. To cope with this dilemma, this study proposed creative situated learning via augmented reality (AR) and developed an AR-based Cosmos Planet Go App to simulate the motion of planets in the universe. This allowed students to understand the characteristics and features of each planet through its simulated motion in the universe. This study adopted a quasi-experimental method and the qualitative analysis to conduct experiments on teaching astronomy in an elementary school in central Taiwan. The control group students were taught using traditional classroom narrative teaching, and the experimental group students were taught using the AR-based Cosmos Planet Go App. The results showed that students who learned with the use of the AR-based Cosmos Planet Go App performed significantly better than the control students on measures of learning effectiveness, learning motivation, and flow experience. Moreover, learning engagement, which occurs when students can use multiple perspectives to solve problems, is the most important element for evaluating the AR-learning environment in creative situations. This study extended the research field of digital technology-assisted learning to the discussion of integrated creative learning environment, which can be used as the basis and reference for scholars' research.

Keywords: Creative situated learning, ARCS motivation model, Augmented reality, Astronomy curriculum

1. Introduction

The concept of situated learning suggests that learning is not merely a result of knowledge imparted through teaching, and that the process of learning is also a source of knowledge. Situated learning theory emphasizes that learning occurs in the situated process of constructing knowledge. Appropriate situated learning contributes to the improvement of teaching effectiveness. From the perspective of the learner, the learning situation can be used to combine life experience with the current situation to produce in-depth knowledge that can be deeply understood and meaningful. If the knowledge learned is separated from the situation, it becomes a cluster of abstract symbols with limited meaning. At present, many studies use creative situated learning to place students into, and have them interact with, the teaching situation, actively exploring and reflecting during the interaction so that they can construct their own knowledge and ability (Chen & Lin, 2016b; Hwang et al., 2020).

A creative learning environment that simulates a real situation through digital technology can incentivize students to be more involved in gaining knowledge, effectively encouraging them to create different ideas and extend the application of the things they learn. Lau (2011) examined the key role of a creative learning environment in design education, focusing on the actual creative work and the learning space. That study showed that virtual reality/augmented reality could provide a learning environment that highly simulated real situations. An imaginative learning space can help students to enjoy a game-like learning environment and find creative fun in the learning process.

Richardson and Mishra (2018) proposed the SCALE creative learning framework to promote understanding and extension of learned knowledge and to enhance its application. This framework for a creative learning environment has been used to guide educators in supporting the construction and development of creative learning environments. The learning environment affecting students' creativity includes the classroom environment, learner participation, and the classroom learning climate. Activities that support creative learning include exploration of new media technologies, engagement in fantasy games, and digital model production and design (David et al., 2013). The creative learning environment does not focus on creating a visually strange or eye-catching learning environment, rather, it helps students to extend the requirements of knowledge through the creative learning environment (Stolaki & Economides, 2018).

Thanks to recent developments in science and technology, scientists have revealed the mysteries of the universe through various space detectors, and the software and hardware for simulating astronomical phenomena have also brought forth many innovative ideas. At present, part of the astronomy curriculum focuses on observing the starry sky, but students' observations may be limited due to the inconvenience of time and place. This problem can be addressed through the aid of technology (Zhang et al., 2014). Some scholars have also noted that students may use augmented reality (AR) devices to carry out authentic learning activities, which can help students to explore the real-world environment, enable them to have a more authentic experience, and enhance their understanding of learning content (Chin et al., 2018a; Chin et al., 2018b; Tseng et al., 2016). Thus, the application of appropriate assisted learning technologies can help students to overcome learning obstacles and make them more willing to understand and learn astronomy without being influenced by these external factors. Li and Keller (2018) argued that most studies have only used scales to measure students' learning motivation and that curricula were actually not designed based on ARCS-based teaching strategies. Therefore, this study used the ARCS Motivation Model and its associated teaching strategies to design a curriculum, and it used the ARCS motivation scale to measure students' learning motivation. Flow experience represents an individual's state of mind. When a person has a flow experience, he/she experiences reality as positive, beneficial, controllable, and challenging and then concentrates on the things going on (Bressler & Bodzin, 2013; Hsu, 2017). This study measured the students' flow experience state to understand whether they were immersed in their learning.

When teaching astronomy, teachers usually face the problem that students can only imagine planetary motion in the universe from textbooks and cannot observe it in reality. This makes it difficult for students to understand the relevant concepts, resulting in poor learning performance and low learning motivation. The connections among the orbits of the planets in the universe as a whole may not be understood; additionally, students may not be motivated to engage in creative performative learning. To address this difficulty in teaching astronomical knowledge, this study proposed developing an AR-based Cosmos Planet Go APP by using creative, situated AR learning, which applies AR technology to simulate the reality of planetary motion in the universe. With this tool, students can discuss the learning content and engage in creative expression around different ideas, which promotes students' learning motivation for astronomical knowledge and allows them to become immersed in the simulation of the universe. This study mainly explored the following issues: (1) differences in astronomy learning performance between students in the upper grades of elementary school exposed to teaching with the AR-based Cosmos Planet Go App and those exposed to traditional classroom narrative teaching; (2) differences in learning motivation among students in the upper grades of elementary school between those using the AR-based Cosmos Planet Go App and those using traditional classroom narrative learning; (3) differences in flow experiences associated with astronomy curricula between students in the upper grades of elementary school who used the AR-based Cosmos Planet Go App and those who used the traditional classroom narrative learning; and (4) the analysis of creative perception with the AR-based Cosmos Planet Go App among students in the upper grades of elementary school.

2. Literature review

2.1. Creative situated learning and application

There have been many good research results on the introduction of situated learning theory, and they are applied most widely in the field of natural sciences. Annotation and comparison through field observation may help students understand the scientific phenomena described in abstract text (Tan et al., 2012). Huang et al. (2013) cited the life experience of convenience store shopping to guide elementary school students to learn addition and subtraction in mathematics. Hwang et al. (2011) constructed a Mindtool based on concept maps to assist learners in a ubiquitous situated learning environment. In the application of Chinese learning, some researchers have combined the difficult and incomprehensible collections of Chinese poems with the situation to deepen the learners' understanding of the meaning of their words and sentences (Shih et al., 2012). These studies have repeatedly shown that combining knowledge that is not easy for students to understand in the classroom with real simulated learning situations can achieve good learning results.

It is very important to support creativity to construct a learning environment that simulates the real situation through interaction. Many scholars have found that learning in a simulated real situation, co-creation and cooperation of learning climate and learners' ideas have been valued and discussed. These are necessary parts to support creativity in the process (Beghetto & Kaufman, 2014). Chen (2007) explored the influence of creative thinking teaching mode on adult English learning, which promoted adult learners to obtain autonomous learning and gain ability to cultivate problem-solving skills and communication and coordination skills through creative learning activities that simulate real situations. Hua (2020) explored the design thinking of museum creative learning resources research and development. It simulated the real situation of the digital learning resources through the actual participation and observation of researchers, and the questionnaire survey of learning resource users. The introduction of design thinking during the development of learning resources requires timely interaction and discussion with participants, which help to transform abstract ideas into concrete content and help to generate ideas quickly.

2.2. Astronomy curriculum and augmented reality

Astronomy has been currently taught in elementary, junior high and high schools in most countries (Fleck & Simon, 2013). The boundless universe has always been the goal that people are striving to explore since ancient times, whose mystery also arouses the curiosity of most students, driving them to further explore the mystery of astronomy (Wu et al., 2015). Observing the operation of celestial bodies and astronomical phenomena is the teaching focus of astronomy curriculums in elementary and junior high schools (Plummer, 2014). However, if students want to observe specific celestial bodies, they have to match the time when the celestial bodies appear and the positions of observing the celestial bodies have also to be correct, which are quite difficult for students taking astronomy in school during the day. As a result, teachers need to take into account the limitations of time and space in teaching.

Many studies have applied AR in teaching. The study specifically designed an AR Chinese character learning game for young learners, and explored its impact on learners' cognitive engagement in classroom learning. The research results showed that students' cognitive engagement has increased significantly in AR-assisted learning activities (Wen, 2020). Chen (2020) combined AR and media with the real learning environment, and provided students with the scaffolding for constructing situated learning, so as to reduce the cognitive load of learners. Experimental results show that compared with traditional video teaching, AR multimedia video teaching method significantly improves students' learning effectiveness and intrinsic motivation, and improves students' satisfaction with English learning. Yousef (2021) explored the use of AR in the lower grades of elementary school students to enhance their creative thinking and increase the possibility of promotion in informal geometric training. The results found that the two research groups had significant differences in motivation and creative thinking skills. AR's presentation of learning content can enhance students' learning and motivate students' willingness to learn.

2.3. ARCS motivation model

The ARCS Motivation Model is proposed by Keller (1987) and explained how to design curriculums with the ARCS Motivation Model. In the element of Attention, it points out that it is necessary to change the previous teaching methods in order to grab students' interest, stimulate their inquiry into problems and arouse their curiosity; in the element of Relevance, it points out that the content of the curriculum needs to satisfy students' personal goals, meet their needs and increase their recognition of the curriculum by combining their previous learning or daily life experience; the element of Confidence illustrates the importance of setting success criteria so that students can realize that they can successfully complete the curriculum with their own efforts; and the element of Satisfaction explains the necessity of providing students with the opportunity to show their skills, teachers' giving students oral praise or substantive rewards after students' successful completing the learning goals set by the teachers, teachers and maintaining a fair reward mechanism. At present, many studies (Deublein et al., 2018; Turel & Sanal; 2018; Wu, 2018) used to combine ARCS teaching strategies with different courses to help students learn, and most study results also showed that applying the ARCS Motivation Model in teaching seemed to improve students' learning motivation and learning effectiveness. Therefore, this study took astronomy as the study subject to explore whether the use of AR-assisted learning system by the fifth and sixth graders will affect their learning motivation and learning effectiveness.

2.4. Flow experience

Flow hereby refers to a state of being, namely a process of one's being absorbed in an event or activity. When one enters the flow state, he/she will not feel bored with the event or activity in which he/she engages, but instead will be completely devoted to that event or activity (Csikszentmihalyi, 1975). Studies on flow were quite diverse, and many scholars (Chen et al., 2018; Yang & Quadir, 2018) also discussed people's behaviors in using new technology, games, shopping, learning, social networking sites and other activities. At the educational level, when a student has a higher flow state, he/she will become more efficient when learning; this is because one feels that learning is joyful and contented in his/her mind (Chang et al., 2017), which means that the more flow experienced one has, the more active one's learning behaviour will be (Hong et al., 2019). Nevertheless, it is really challenging for current education to enable students to achieve their flow states in learning (Ibáñez et al., 2014). There were studies (Hong et al., 2019; Kao et al., 2019) showing that learning with multimedia-related textbooks can effectively improve students' flow state.

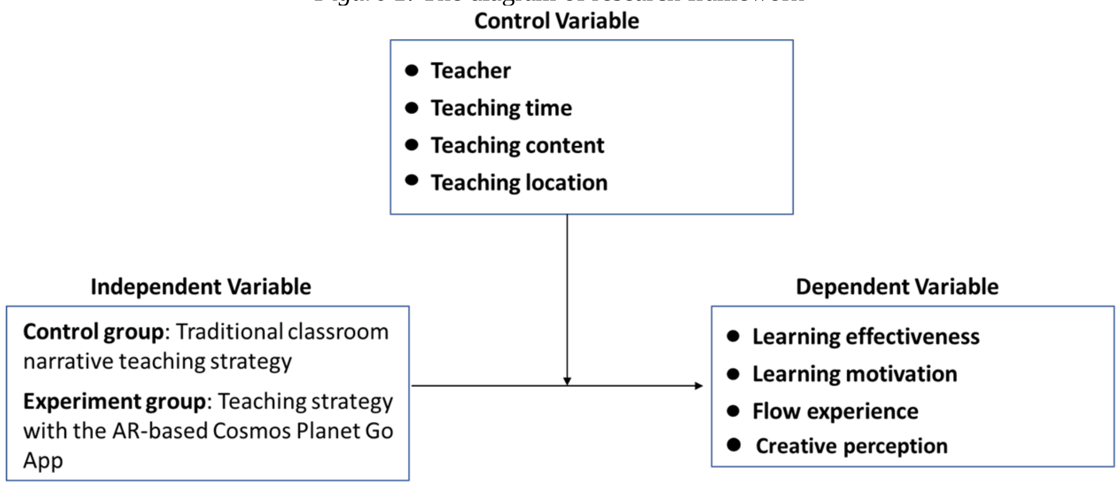
3. Research methodology

3.1. Experiment design

The research framework was shown in Figure 1. This study adopts the quasi-experimental method to conduct teaching experiments on astronomical knowledge in an elementary school of central Taiwan. The independent variable referred to the difference in the teaching strategies used in the experiment. The experimental group used the teaching strategy of AR-based Cosmos Planet Go App, while the control group used the traditional classroom narrative teaching strategy. The dependent variables were learning effectiveness, learning motivation, flow experience, and creative perception, and it discussed the differences in learning effectiveness, learning motivation, flow experience, and creative perception under different teaching strategies. In the control variables, teachers, teaching time, teaching content and teaching location of the two groups are the same. The operation definitions of learning motivation, learning effectiveness, flow experience and creative perception are described. Learning motivation refers to arousing the motivation of students to learn, and continuing to carry out learning activities, so that students' learning activities tend to the learning goals set by the teacher (Keller, 2010). Learning effectiveness refers to the changes in students' academic performance after participating in learning activities (Chen & Lin, 2016a). Flow experience refers to a state in which a person is completely immersed in a certain activity, ignoring the existence of other affairs. This kind of experience itself brings great joy and it is a subjective psychological feeling (Pearce et al., 2005). Creative perception uses the SCALE creative learning framework proposed by Richardson and Mishra (2018) to measure creative learning perception. The SCALE includes the classroom environment, classroom learning climate, and learner participation. Based on the above experimental design, the research hypotheses are described as follows:

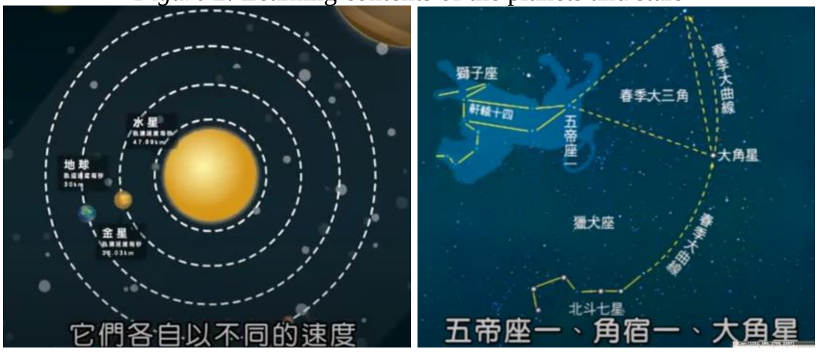
- The learning effectiveness of the teaching strategy with the AR-based Cosmos Planet Go App is better than that of the traditional classroom narrative teaching strategy.
- The learning motivation of the teaching strategy with the AR-based Cosmos Planet Go App is higher than that of the traditional classroom narrative teaching strategy.
- The flow experience of the teaching strategy with the AR-based Cosmos Planet Go App is higher than that of the traditional classroom narrative teaching strategy.
- The creative perception of the teaching strategy with the AR-Based Cosmos Planet Go App is better than that of traditional classroom narrative teaching strategy.

Figure 1. The diagram of research framework



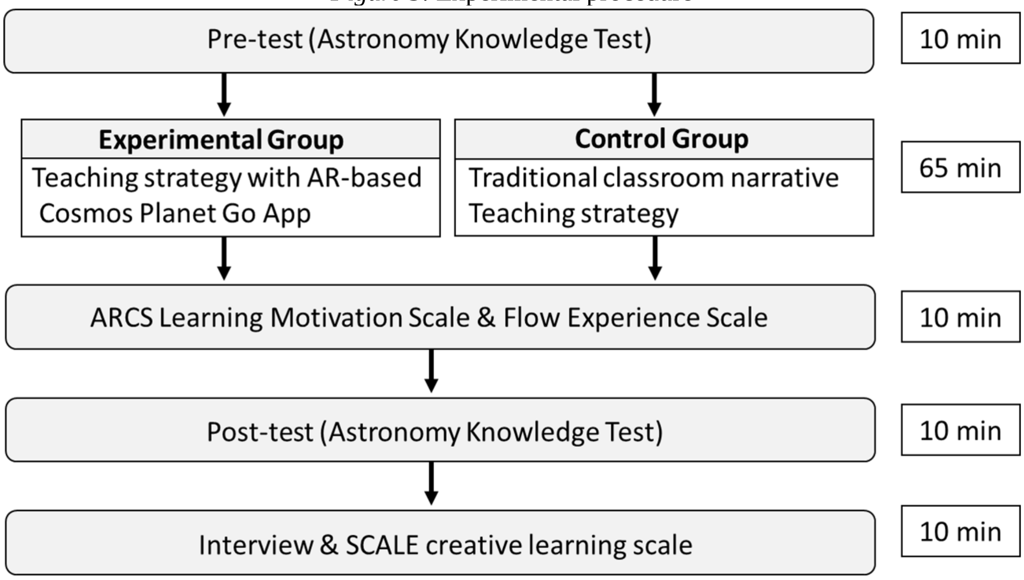
The participating students are students of the fifth and sixth grades because grades fifth and sixth of Taiwan elementary school have learned about the universe and planets. The experimental group and the control group are composed of students from one class in the fifth grade and one class in the sixth grade respectively. The Experimental group had 40 students, including 10 males and 10 females of fifth grade and 10 males and 10 females of sixth grade. The control group has 40 students, including 9 males and 10 females of fifth grade and 9 males and 12 females of sixth grade. The teaching course is the science course of elementary schools. The learning contents include the moon motion and rotation, the relationship between the moon orbit and the sun, the planets of the solar system and the distance of interstellar groups. The left side of Figure 2 simulates the situation of planetary motion in the universe, and the right side of Figure 2 shows the positions of stars in the sky at night. The prior knowledge on astronomical knowledge possessed by the two groups of students is the consistent, and there is no significant difference.

Figure 2. Learning contents of the planets and stars



The experimental procedure is shown in Figure 3. The pre-test questions and post-test questions prepared were reviewed by three experts, and the questions with unclear or ambiguous meanings were deleted, and the exam questions were determined after item analysis and discrimination analysis. Item analysis can improve the quality of test questions, thereby improving the reliability and validity of the test. The greater the item-difficulty index, the easier the question is. Discrimination analysis is an assessment of the question proportion of papers that distinguish high-ability and low-ability. The higher the discrimination index is, the higher the consistency between the response of the subjects and the total score is (Hogan, 2007; Yu, 2011). After statistical analysis, the pre-test questions and post-test questions were of moderate difficulty and high discrimination. The teacher of the control group taught astronomical knowledge in an oral manner, and guided students through the pictures in the textbook and study sheets to strengthen students' exploration of learning astronomical knowledge, the connection of related knowledge concepts. Teachers gave timely feedbacks on incorrect concepts and rethought the study sheets, so as to achieve learning progress. The learning activities of astronomy curriculums for the students of control group and experimental group in this study are shown in Table 1.

Figure 3. Experimental procedure



All participating students were asked to fill in the IMMS (Instructional Materials Motivational Scale) and the flow experience test scale. They subsequently attended the astronomy achievement post-test. Lastly, the students in the experimental group were interviewed after class. The learning situation of the control group and the experimental group is shown in Figure 4. The IMMS scale developed by Keller (2010) has 4 dimensions included Attention, Relevance, Confidence and Satisfaction. The Cronbach's alphas of the 4 dimensions were 0.878, 0.861, 0.848 and 0.929 respectively. As for the Flow Experience Scale developed by Pearce et al. (2005) and was used to measure the students' overall flow experience. The Cronbach's alpha was 0.885, which was acceptable in reliability. A total of 20 students from the experimental group were randomly selected for after-class interviews. Each student spent an average of 8-10 minutes in the interview and filled in the SCALE questionnaire. The interview content included the operation convenience of the AR-based Cosmos Planet Go App, learning experience and perception to creative learning environment.

Figure 4. Learning in the control and experimental groups

(a) (b)

Table 1. ARCS Motivation model curriculum design

ARCS Factor	Teaching strategy	
	Control group	Experimental group
Attention	1. Wonderful films and pictures, together with briefing teaching to grab students' senses. 2. From the content of teaching, ask questions to make students curious, and then trigger them to think. 3. The teaching briefing is presented with excellent videos and pictures, which is different from the previous teaching methods.	1. Combine AR with the simulated planets' rotation and revolution to arouse students' curiosity. 2. Let the students practice with the multiple-choice questions. After they answer the questions, the questions answered with wrong answers will be displayed on the tablet computer screen for them to understand which aspects of the content are still unclear to them, by which they are aroused to think. 3. The planets' appearances are presented in the form of AR together with dynamic visual presentation, which is distinguished from the previous teaching methods.
Relevance	1. Explain clearly the teaching objectives and learning priorities of astronomy curriculum. 2. Allow the students to ask questions. Explain the questions according to the questions raised by the students. Teachers may also ask the students questions. 3. The teaching content provides familiar examples to help students understand.	1. Clearly present the features and learning priorities of each planet 2. After the students answer the exercise questions, they are immediately shown with their answer results and all the correct answers on the tablet computer screen. 3. Each planet's features is described by the things that students are exposed to in their daily lives, helping them to understand the content more quickly.
Confidence	1. Define fair scoring items and criteria and establish objective rules and incentives. 2. The in-class worksheets are designed as the level of difficulty at which students can accomplish. 3. In the process of completing the in-class worksheets, students are provided with appropriate practice opportunities and feedback to help them complete the in-class worksheets.	1. The exercise questions have fair scoring items and criteria. If the student's answers are all correct, he/she will be given a verbal encouragement. 2. The exercise questions are designed to be a level of difficulty at which the students are capable of completing, and the App is easy to operate such that students can get started quickly. 3. Provide the students with appropriate practice opportunities and feedback to help them complete the exercise questions.

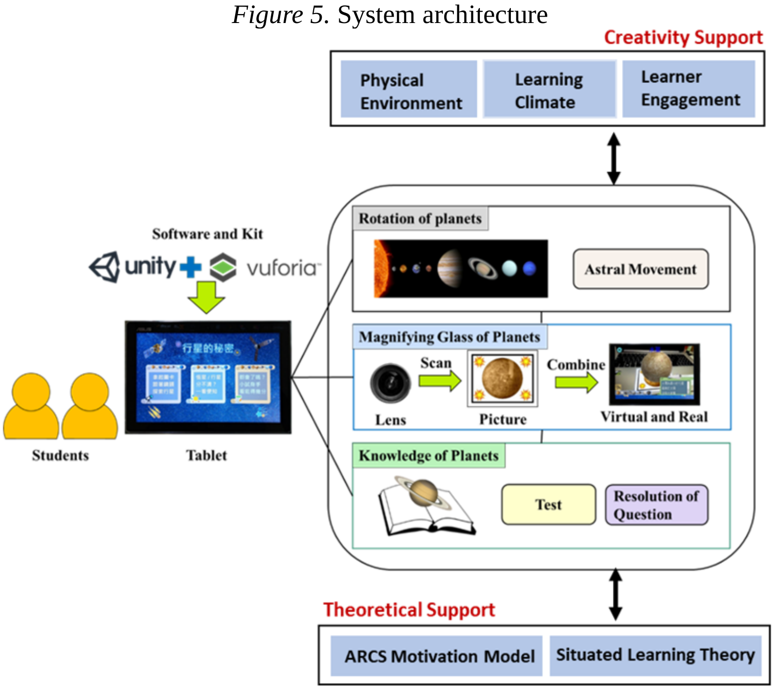
Satisfaction	1. Students complete the in-class worksheets according to the content of the curriculum. 2. Teachers provide students with useful information, feedback and timely reward. 3. Ensure fair scoring mechanism and rewarding criteria.	1. Students complete the exercise questions in the tablet computer according to what they have learned in the curriculum. 2. The App provides students with useful information, helpful feedback and timely rewards students. 3. Exercise questions have a fair scoring mechanism and rewarding criteria.

3.2. Design of AR-based Cosmos Planet Go App

Creative situated augmented reality learning refers to constructing a learning environment that simulates the real situation and supports creativity through AR technology. The creative situated augmented reality learning proposed is the integration of situated learning theory (Lave & Wenger, 1990), ARCS motivation theory (Keller, 1987) and creative learning environment model (Richardson & Mishra, 2018) as shown in Figure 5. The creative learning environment model includes physical environment, learning climate and learner engagement. The physical environment means that the learning environment should be open, allowing students in each group to collaborate and discuss with each other, and have a variety of rich learning content and resources available for students to read at any time (Peterson & Harrison, 2005; Warner & Myers, 2010). The learning climate refers to an open learning climate where students can freely discuss new ideas and trust each other. Creativity tends to flourish when there is an opportunity for exploration and learning and when innovation is valued (Kozbelt et al., 2010). Learner engagement refers to the learning tasks that students actually participate in. All members of a learning environment are seen as co-learners and co-teachers, emphasizing the importance of the learning process (Jeffrey & Craft, 2004). Learners can focus on questions and answer after thinking. These can be achieved by stimulating students' intrinsic motivation (Peterson & Harrison, 2005) or by training students to use various media to express ideas so that they can understand what the learner is actually doing.

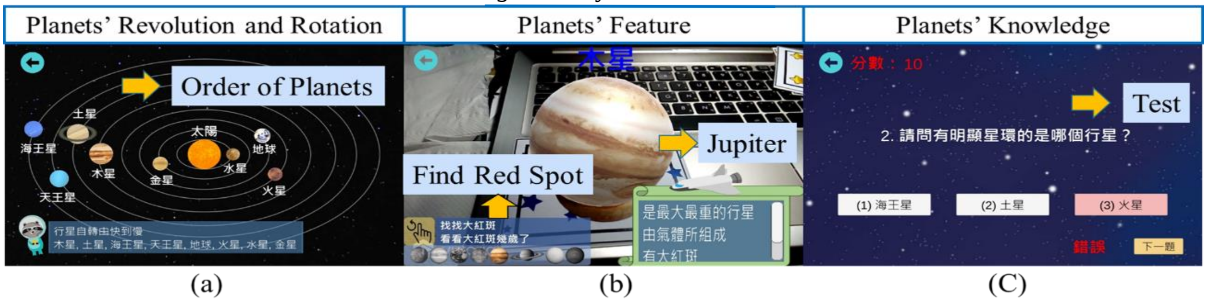
The AR-based Cosmos Planet Go App implemented was written in Unity 3D and C# in the system interface and functions. The AR functions used Vuforia to develop engine, and 3D model materials of celestial bodies are obtained from the 3D Warehouse. Students use the system on a tablet to learn. The system architecture is shown in Figure 5.

Figure 5. System architecture



The learning App has three main functions: Planets' Revolution and Rotation, Magnifying Glass of Planets and Planets' Knowledge. In the function of Planets' Revolution and Rotation, it allows students to understand the planets' rotation, revolution and distance from the sun, where students can magnify, shrink and move by gesture touch so that they can clearly observe the planets' rotational directions and positional order. The system also simulates the planet's rotation and revolution patterns, where students can click on the star icons on lower left corner for more detailed explanations. In the function of Magnifying Glass of Planets, it enables students to observe the appearance of planets carefully. As long as they pick up the tablet and scan the pictures of planets through the lens, the planets' 3D models will appear on the screen of the tablet and are integrated into the real environment. Students can magnify, shrink and rotate the planets through the gesture touch to find the features of each planet. They can also slide the planet information bar to learn about the planets. As in the function of Planets' Knowledge, it can help students to review. After completing the curriculum, students can answer the questions in tablet computers through gesture touch. Whether they answer correctly or incorrectly, the system will give students corresponding answers. Students can clarify the parts they do not understand so as to fulfil the review purpose. Each function on the system screen is shown in Figure 6.

Figure 6. System screen



In the construction of the creative situated augmented reality learning environment, students can not only use tablets to learn astronomy knowledge and discuss with peers but also use the intelligent computers built in the classroom to check planetary data at any time and experience the situational simulation operation of large-screen touch planets. During the learning process, students in different groups are allowed to discuss with each other, and each group is encouraged to put forward different ideas. Through the answers of different groups, the truth of astronomical knowledge can be verified, allowing students to explore knowledge and clarify the misunderstanding in their own learning concepts. When students put forward different points of view to express their feedback on the operation of the planet, the teacher will also help guide students to reflect, and then deepen the correct concept and increase the interest in participation. Through such a creative situated augmented reality learning environment learning process, students can express different creative thinking and experience planetary simulation at any time to achieve the positive effect of physical environment, learning climate, and learner engagement.

4. Experimental results

4.1. The influence of learning effectiveness

The results of independent samples *t*-test as shown in Table 2, there were no significant differences in the pre-test results between different groups, where $t(73.060) = -1.439$, $p = .155$. The students in the control group and the experimental group had the same understanding and awareness of astronomical knowledge before they participated in the learning activities. As shown in Table 3, the results of independent samples t-test presented that there were significant differences in the post-test results between different groups, where $t(62.073) = -2.367$, $p = .021$, indicating that the experimental group students had better learning effectiveness than the control group students did.

Table 2. *t*-test for different groups in their pre-test scores

	Mean (*SD*)		*t*	*p*
	Control group ($N = 40$)	Experimental group ($N = 40$)		
Pre-test	52.400 (33.675)	62.050 (25.806)	-1.439	.155

Table 3. *t*-test for different groups in their post-test scores

	Mean (*SD*)		*t*	*p*
	Control group ($N = 40$)	Experimental group ($N = 40$)		
Pre-test	82.000 (22.151)	91.550 (12.677)	-2.367	$.021^{*}$

Note. $^{*}p < .05$.

4.2. The influence of learning motivation

Independent samples *t*-test was applied to students' learning motivation in all 4 dimensions as shown as Table 4. In the dimension of Attention, there were significant differences between different groups, where $t(67.491) = -2.419$, $p = .018$; significant differences were found in the dimension of Relevance, where $t(78) = -2.411$, $p = .018$; significant differences were found in the dimension of Confidence, where $t(63.563) = -2.849$, $p = .006$; significant differences were also found in the dimension of Satisfaction, where $t(63.132) = -2.456$, $p = .017$; there were significant differences in ARCS, where $t(65.184) = -2.759$, $p = .008$. The results showed that the "AR-based Cosmos Planet Go App" can effectively grab students' motivation, inspire their inquiry into problems and arouse their curiosity, rendering them outperform the students learning by classroom narration teaching. In the classroom, students actively used the AR-based Cosmos Planet Go App, and they were particularly interested in the generated situation of the planetary motion connection in the universe. Students discussed the distance, temperature and weight of planets with each other. As they saw the simulated real AR-based planetary motion in the universe, students asked whether the planets may collide, and whether there may be planets that do not move according to the orbit. All these learning interactions showed that the teaching strategy of creative situated AR-based learning attracted students to concentrate on learning astronomical knowledge.

Table 4. t-test of different groups in the 4 dimensions of ARCS

	Mean (*SD*)		*t*	*p*
	Control group (*N* = 40)	Experimental group (*N* = 40)		
Attention	4.060 (0.994)	4.515 (0.655)	-2.419	$.018^{*}$
Relevance	4.060 (1.039)	4.530 (0.663)	-2.411	$.018^{*}$
Confidence	3.925 (1.097)	4.500 (0.653)	-2.849	$.006^{**}$
Satisfaction	4.130 (1.088)	4.620 (0.640)	-2.456	$.017^{*}$
ARCS	4.050 (0.961)	4.543 (0.597)	-2.759	$.008^{**}$

Note. $^{*}p < .05$; $^{**}p < .01$.

4.3. The influence of flow experience

The analysis results of independent samples *t*-test as shown in Table 5, there were significant differences in the flow experience between different groups, where $t(72.598) = -13.912$, $p < .001$, indicating that after using the "AR-based Cosmos Planet Go App" to learn during the course, students were more immersed in their learning than those learning with the classroom narrative teaching way.

Table 5. t-test of different groups in their flow experience

	Mean (*SD*)		Mean (*SD*)	*p*
	Control group (*N* = 40)	Experimental group (*N* = 40)		
Flow	2.432 (0.450)	4.075 (0.596)	-13.912	$< .001^{***}$

Note. $^{***}p < .001$.

4.4. Interview analysis

This section discussed the interview analysis for participating the experiment process. Students (S05 and S12) said that they thought it was incredible to see the 3D planetary motion on the tablet, which can stimulate their motivation for learning and more creative thinking, and they could discuss with their classmates about the different characteristics and colors of each planet. Student (S03) said that in the motion of the planetary orbit, they can see Taiwan during the rotation by themselves. They unconsciously wanted to draw the method of finding the Polaris by themselves and provide it to classmates as a reference. Students (S07 and S17) said that this APP made it easier for them to learn planetary knowledge, and also made them actively want to participate in the learning activities of the course, and they wanted to recommend this APP to their good friends to learn together. Students (S09, S14 and S20) said that the system was very easy to use, especially the use of 3D animation to show the simulated motion of the real planet, which gave them more confidence in learning the knowledge of the planet, and also enabled them to discuss knowledge that was not understood with their classmates and review it again through the APP.

The SCALE developed by Richardson and Mishra (2018) was employed to measure students' perception of creative learning environment as shown in Table 6. In the dimension of physical environment, the item of PE1 received 85% of highly agree support from students. In the dimension of learning climate, the item of LC3 won

90% support from students. In the dimension of learner engagement, the items of LE4 and LE3 were supported by 95% and 90% for highly agree. According to the results, the most important students' perception about creative learning environment was to demonstrate an interest in or enthusiasm for the activity beyond being on task. Students' use of multiple perspectives/viewpoints/ways of knowing or various modes of investigation/problem solving is secondary importance. From the dimension of scale, learner engagement is the most important.

Table 6. Analysis of learners' perception for creative learning environments

Question		Mean	*SD*	Percentage of each question in 4-point Likert scale (%)			
				Disagree	Minimal Agree	Moderate Agree	Highly Agree
Physical Environment:							
PE1:	A variety of resources are available and accessible to students.	3.85	0.37	0%	0%	15%	85%
PE2:	Examples of student work appear in the space.	2.55	0.60	5%	35%	60%	0%
PE3:	A variety of work stations or areas are available to students.	3.15	0.75	0%	20%	45%	35%
PE4:	The furniture allows for multiple arrangements and configurations.	3.10	0.79	0%	25%	40%	35%
Learning Climate:							
LC1:	Students are involved in discussions among themselves, with or without the teacher, that deepen their understanding.	3.85	0.37	0%	0%	15%	85%
LC2	The students are caring, respectful, and value differences.	3.60	0.68	0%	10%	20%	70%
LC3:	The teacher is a facilitator, co-learner, explorer, or inquirer with students.	3.90	0.31	0%	0%	10%	90%
LC4:	Mistakes, risk-taking, and novel ideas are valued or encouraged.	3.20	0.52	0%	5%	70%	25%
Learner Engagement:							
LE1:	Students are involved in tasks that are open-ended and/or involve choice.	3.50	0.61	0%	5%	40%	55%
LE2:	Students are involved in activities that may include inquiry, project based learning, or interdisciplinary tasks.	3.60	0.50	0%	0%	40%	60%
LE3:	Students use multiple perspectives/viewpoints/ ways of knowing or various modes of investigation/problem solving.	3.90	0.31	0%	0%	10%	90%
LE4:	Students demonstrate interest in or enthusiasm for the activity beyond being "on task."	3.95	0.22	0%	0%	5%	95%
LE5:	Students spend time	3.30	0.73	0%	15%	40%	45%

	developing ideas for deeper understanding and/or reflecting on their learning.						
LE6:	Students work at their own pace and/or time is used flexibly.	3.85	0.37	0%	0%	35%	65%

5. Discussion

Many current studies have shown that the use of ARCS teaching strategy design can help students improve their learning effectiveness (Hung et al., 2013; Turel & Sanal, 2018; Wu, 2018). This study again verified that technology-assisted learning designed with ARCS teaching strategy can stimulate students' learning. According to the research results, teaching using AR-based Cosmos Planet Go App can improve students' learning motivation and learning effectiveness more than the traditional classroom narrative teaching method. Some past literature on digital technology-assisted learning has considered that digital technology-assisted learning environments support training of students' creative learning (Jahnke & Liebscher, 2020; Yeh et al., 2019). Digital technology-assisted learning focusing on the teaching scene can provide the guidance of teaching activities for students' creative learning and create a learning environment conducive to cultivating students' creative expression. This study proposed using situated augmented reality learning environment to support creative learning. Support for creative learning was constructed through an interactive learning environment that simulates real situations. Students discussed what they have learned and expressed their ideas creatively by simulating the real situation of how the stars operate in the universe.

This study proposed a creative situated augmented reality learning model to solve the students' problem in learning the abstract astronomy knowledge and focus on the key points of learning by simulating planetary operations through situated contexts. In addition to discussing learning effectiveness, learning motivation, and learning immersion, a creative situated augmented reality learning environment is the most important aspect of students' learning experience. This study found that the aspect of learning participation was the most important, which was not considered by many related literatures on the support of digital technology-assisted learning environments in the past. This study advocated the support of digital technology-assisted learning environments in terms of creative environment construction and implementation, the interactive E-learning system could focus on the modules that provide students with diverse perspectives to solve learning tasks, as well as the ARCS-based augmented reality curriculum design to promote students' participations in learning activities.

6. Conclusion

Augmented Reality can effectively enable students to observe and understand the course content. Teaching materials designed via ARCS teaching strategies can help students improve their learning effectiveness. This study proposed creative situated augmented reality learning environment combines situated learning theory, the characteristics of augmented reality with the ARCS motivation theory and creative learning environment model to develop the AR-based Cosmos Planet Go App. Students can understand the characteristics and features of each planet through this simulated universe motion situation. According to the analysis results, it can be seen that student learning with an AR-based Cosmos Planet Go App outperformed the ones learning only with the classroom narrative teaching method as the system can effectively assist students in their learning. The practical teacher in elementary schools can teach astronomy knowledges using the AR-based Cosmos Planet Go App to improve the learning effectiveness, learning motivation and enhance flow experience. Students can understand the characteristics and features of each planet through this simulated universe motion situation. At the academic contribution, this study proposed the creative situated learning with AR to solve the teaching in astronomy curriculums that is abstract and difficult to be understood. It constructed learning situations through AR so that learners can learn abstract concepts. It also enabled scholars to have more applications and discussions on the research topics of creative situated learning with AR.

Although more studies have discussed how digital technology-assisted learning environments support the construction and evaluation of students' creative learning, most of them have no clear principles on how to integrate students' creative learning into digital technology-assisted learning environments. In this study, we found that the dimension of learning engagement, a mode in which students could use multiple perspectives to solve the problems is the most important, and followed by students' showing interest or enthusiasm for learning activities, instead of just performing tasks, as secondary. The results can be as a reference by future scholars with a priority to focus on supporting learner engagement when conducting research on digital technology-assisted learning environments supporting creative situations. Many scholars have successively discussed the design of teaching courses with the ARCS model. However, the most past literature took English as learning theme, and they used it to improve learning effectiveness by enhancing learning motivation. It is not easy to learn and understand astronomy knowledge without guidance by situation. This study used the AR to present the situation of planetary motion in the universe, so that students could understand astronomy knowledge clearly. Therefore, this study created the AR-based Cosmos Planet Go App support creativity and allowed students to observe the planetary motion that was usually difficult to observe at close range in real life. It can help teaching application of astronomy knowledge, and it may also enable practice teachers to have a variety of teaching methods.

7. Limitations and future research

It was suggested that the extension and analysis of different learning styles in the situated learning with AR can be added into the follow-up of this research, as well as what kind of learning interactivity should be possessed by learners of different learning styles in the situation constructed by AR, and differences in their influence on learning effectiveness, learning motivation and flow experience. In the experiment of this study, the 3D effect can only be effectively presented in a well-lit classroom because the simulated planet motion animation of augmented reality is presented on a tablet, If the classroom is lack of light, the effect of the augmented reality presentation may be affected. The AR-based Cosmos Planet Go App developed can only be used on tablet. Because of the different sizes of smartphone screens, it cannot effectively present virtual reality 3D animations that simulate real situations. Due to limited resources, the experiment time of this study was short, and the experiment time can be extended for future follow-up studies.

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References

Bressler, D. M., & Bodzin, A. M. (2013). A Mixed methods assessment of students' flow experiences during a mobile augmented reality science game. *Journal of Computer Assisted Learning, 29*(6), 505-517.

Beghetto, R. A., & Kaufman, J. C. (2014). Classroom contexts for creativity. *High Ability Studies*, *25*(1), 53–69

Chang, C. C., Liang, C., Chou, P. N., & Lin, G. Y. (2017). Is game-based learning better in flow experience and various types of cognitive load than non-game-based learning? Perspective from multimedia and media richness. *Computers in Human Behavior, 71*, 218-227.

Chen, H.-L. (2007). The Effect of creative teaching on adult english learners based on the ATDE model. *Bulletin of Diwan College of Management*, *2*(1), 57-70.

Chen, C. C., & Lin, P. H. (2016a). Development and evaluation of a context-aware ubiquitous learning environment for astronomy education. *Interactive Learning Environments*, *24*(3), 644-661.

Chen, C. H. (2020). AR videos as scaffolding to foster students' learning achievements and motivation in EFL learning. *British Journal of Educational Technology*, *51*(3), 657-672.

Chen, H.-R., & Lin, Y.-S. (2016b). An Examination of digital game-based situated learning applied to Chinese language poetry education. *Technology, Pedagogy and Education*, *25*(2), 171-186.

Chen, Y. M., Hsu, T. H., & Lu, Y. J. (2018). Impact of flow on mobile shopping intention. *Journal of Retailing and Consumer Services, 41*, 281-287.

Chin, K. Y., Lee, K. F., & Chen, Y. L. (2018a). Using an interactive ubiquitous learning system to enhance authentic learning experiences in a cultural heritage course. *Interactive Learning Environments, 26*(4), 444-459.

Chin, K. Y., Wang, C. S., & Chen, Y. L. (2018b). Effects of an augmented reality-based mobile system on students' learning achievements and motivation for a liberal arts course. *Interactive Learning Environments, 27*(7), 927-941. https://doi.org/10.1080/10494820.2018.1504308

Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. San Francisco: Jossey-Bass.

Deublein, A., Pfeifer, A., Merbach, K., Bruckner, K., Mengelkamp, C., & Lugrin, B. (2018). Scaffolding of motivation in learning using a social robot. *Computers & Education, 125*, 182-190.

Fleck, S., & Simon, G. (2013). An Augmented reality environment for astronomy learning in elementary grades: An Exploratory study. In *Proceedings of the 25th Conference on l'Interaction Homme-Machine* (pp. 14). ACM.

Hogan, T. P. (2007). *Educational assessment: a practical introduction*. John Wiley.

Hong, J. C., Tsai, C. R., Hsiao, H. S., Chen, P. H., Chu, K. C., Gu, J., & Sitthiworachart, J. (2019). The Effect of the "Prediction-observation-quiz-explanation" inquiry-based e-learning model on flow experience in green energy learning. *Computers & Education, 133*, 127-138.

Hua, C.-W. (2020). Design thinking and developing museum creative learning resources: The Mobile Museum of the National Museum of History. *Journal of Museum & Culture*, *20*, 83-112

Hsu, T. C. (2017). Effects of gender and different augmented reality learning systems on English vocabulary learning of elementary school students. *Universal Access in the Information Society, 18*(2), 315-325.

Hwang, G.-J., Shi, Y.-R., & Chu, H.-C. (2011). A Concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology*, *42*(5), 778-789.

Hwang, W.-Y., Zhao, L., Shadiev, R., Lin, L.-K., Shih, T. K., & Chen, H.-R. (2020). Exploring the effects of ubiquitous geometry learning in real situations. *Educational Technology Research and Development*, *68*, 1121-1147.

Huang, S.-H., Wu, T.-T., Chen, H.-R., Yang, P.-C., Huang, Y.-M. (2013). Development of a context-aware game for conducting ubiquitous mathematics learning activities. *International Journal of Mobile Learning and Organisation*, *7*(3/4), 239-252.

Hung, I. C., Chao, K. J., Lee, L., & Chen, N. S. (2013). Designing a robot teaching assistant for enhancing and sustaining learning motivation. *Interactive learning environments, 21*(2), 156-171.

Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, *71*, 1-13.

Jahnke, I., & Liebscher, J. (2020). Three types of integrated course designs for using mobile technologies to support creativity in higher education. *Computers & Education, 146*, 103782. https://doi.org/10.1016/j.compedu.2019.103782

Jeffrey, B., & Craft, A. (2004). Teaching creatively and teaching for creativity: Distinctions and relationships. *Educational Studies, 30*(1), 77–87.

Kao, G. Y. M., Chiang, X. Z., & Foulsham, T. (2019). Reading behavior and the effect of embedded selfies in role-playing picture e-books: An Eye-tracking investigation. *Computers & Education, 136*, 99-112.

Keller, J. M. (1987). Strategies for stimulating the motivation to learn. *Performance & Instruction, 26*(8), 1-7.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. Springer.

Kozbelt, A., Beghetto, A. B., & Runco, A. M. (2010). Theories of creativity. In J. C. Kaufman & R. J. Sternberg (Eds), *The Cambridge Handbook of Creativity* (pp. 447-459). Cambridge University Press.

Lau, K.-W. (2011). The Importance of creative learning environment in art & design education. *Design Journal of Shih Chien University*, *5*, 195-219.

Lave, J., & Wenger. E. (1990). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Li, K., & Keller, J. M. (2018). Use of the ARCS model in education: A Literature review. *Computers & Education, 122*, 54-62.

Pearce, J. M., Ainley, M., & Howard, S. (2005). The EBB and flow of online learning. *Computers in human behavior, 21*(5), 745-771.

Peterson, R. E., & Harrison III, H. L. (2005). The Created environment: An Assessment tool for technology education teachers: creativity doesn't just happen by chance; the prepared environment nourishes it. *The Technology Teacher*, *64*(6), 7–11.

Plummer, J. D. (2014). Spatial thinking as the dimension of progress in an astronomy learning progression. *Studies in Science Education*, *50*(1), 1-45.

Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCALE. *Thinking Skills and Creativity*, *27*, 45-54.

Shih, W.-C., Tseng, S.-S., Yang, C.-C., Lin, C.-Y., & Liang, T. (2012). A Folksonomy-based guidance mechanism for context-aware ubiquitous learning: A Case study of Chinese scenic poetry appreciation activities. *Educational Technology & Society*, *15*(1), 90-101.

Stolaki, A, & Economides, A. A. (2018). The Creativity challenge game: An Educational intervention for creativity enhancement with the integration of Information and Communication Technologies (ICTs). *Computers & Education*, *123*, 195-211.

Tan, T.-H., Lin, M.-S., Chu, Y.-L., & Liu, T.-Y. (2012). Educational affordances of a ubiquitous learning environment in a natural science course. *Educational Technology & Society*, *15*(2), 206–219.

Tseng, H. W., Tang, Y., & Morris, B. (2016). Evaluation of iTunes university courses through instructional design strategies and m-learning framework. *Educational Technology & Society, 19*(1), 199-210.

Turel, Y. K., & Sanal, S. O. (2018). The Effects of an ARCS based e-book on student's achievement, motivation and anxiety. *Computers & Education, 127*, 130-140.

Warner, S. A., & Myers, K. L. (2010). The Creative classroom: The Role of space and place toward facilitating creativity. *The Technology Teacher, 69*(4), 28-34.

Wen, Y. (2020). Augmented reality enhanced cognitive engagement: Designing classroom-based collaborative learning activities for young language learners. *Educational Technology Research and Development*, 1-18.

Wu, S. J., Chu, H. C., & Yang, K. H. (2015). An Web quest-based context-aware u-learning system to improve students' problem solving and communication abilities in astronomy inquiry activities. In *2015 IIAI 4th International Congress on Advanced Applied Informatics* (pp. 319-322). IEEE.

Wu, T. T. (2018). Improving the effectiveness of English vocabulary review by integrating ARCS with mobile game-based learning. *Journal of Computer Assisted Learning, 34*(3), 315-323.

Yang, J. C., & Quadir, B. (2018). Individual differences in an English learning achievement system: Gaming flow experience, gender differences and learning motivation. *Technology, Pedagogy and Education*, *27*(3), 351-366.

Yeh, Y.-C., Rega, E. M., & Chen, S.-Y. (2019). Enhancing creativity through aesthetics-integrated computer-based training: The effectiveness of a FACE approach and exploration of moderators. *Computers & Education*, 139, 48-64.

Yousef, A. M. F. (2021). Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school. *Journal of Computer Assisted Learning, 37*(4), 966-977. https://doi.org/10.1111/jcal.12536

Yu, M.-N. (2011). *Educational test and assessment*. Psychological Publisher.

Zhang, J., Sung, Y. T., Hou, H. T., & Chang, K. E. (2014). The Development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction. *Computers & Education, 73*, 178-188.

Appendix

Pretest Questions

1. What kind of planets are the stars on the constellation chart?
2. What are the main causes of craters on the surface of the Moon?
3. What is the order of the eight planets from nearest to farthest from the Sun?
4. If you see a rainbow in the East after a rain, which direction is the Sun located?
5. In the region where the Tropic of Cancer passes, which direction does the noon pole shadow face in winter?
6. Which planet is the largest in size?
7. Which planet has the obvious ring?
8. Which planet is covered in a thick cloud of sulfuric acid?
9. Does the feature of the moon going around the Earth mean that the side of the moon facing the Earth remains facing us?
10. What is the order of planetary rotation speed from slowest to fastest?

Posttest Questions

1. When the constellation is in motion, will the distance between the stars remain the same?
2. Observe craters on the surface of the moon. Is it true that the surface is damaged and uneven due to the heat of the moon's combustion as it orbits close to the sun?
3. What is the order of the eight planets from the sun from farthest to nearer?
4. In the area where the Tropic of Cancer passes, the sun rises from the northeast in the morning in the summer, and from which position will the sun set in the afternoon?
5. Is it true that planets usually revolve in the same direction as the star they orbit, and that the hotter the star's surface, the brighter it gets?
6. Which planet would float if placed in water?
7. Which planet is famous for its beautiful star rings, and is it the first planet to be discovered with star rings?
8. How long does it take for the moon to make a circle around the earth?
9. What is the order of the planet's rotation speed from fast to slow?
10. Which planet is characterized by the greenhouse effect?

Interview question

1. For learning with the AR-Based Cosmos Planet Go App, what is the help for astronomy learning?
2. For learning with the AR-Based Cosmos Planet Go App, what is the degree of improvement in learning motivation for participating in astronomy courses?
3. For learning with the AR-Based Cosmos Planet Go App, what is the degree of change in the learning immersion of participating in astronomy courses?
4. When learning with the AR-Based Cosmos Planet Go App, what is the ease of operation for using the system?