A moon observation system for learning the lunar concepts in Astronomy education

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Structured abstract

BACKGROUND

Observation and inference are important skills for engineers. By observing the sun, moon, and stars, and then use scientific methods to induce the rules and causes of their movement that can enhance their thinking and inference abilities. The moon is the closest celestial body to the earth, so it is a suitable target for observation and investigation for K12 students. However, observing lunar phases requires long-term involvement, and it is often obstructed by a bad weather or tall buildings. All these factors prevent them from developing observation and inference skills during this unit in formal learning.

PURPOSE

In this study, a moon observation system is proposed using the augmented reality (AR) technology and sensor functions of mobile devices to help students observe lunar phases.

DESIGN/METHOD

By holding the mobile device towards the moon, the system will show the virtual moon overlapping with the real moon on the screen. The virtual moon can be seen even if the real moon is obstructed. In addition, the system allows students to record the lunar data easily, including lunar phases, azimuth and elevation angles as well as the date and time of observation.

RESULTS

A teaching experiment was conducted to investigate students' learning effectiveness and attitudes after using the proposed system for learning lunar concepts. The results showed that the proposed system is an effective tool for astronomy education. Most students considered it easy to operate and would like to use it for observing the lunar phase in the future.

CONCLUSIONS

This study could be a helpful reference for engineering teachers who want to design mobile instruments assisted learning in authentic environment. The system can shorten the learning process by setting different dates and times for observation, and it can solve the problem of unable to observe the moon due to a bad weather or tall buildings.

KEYWORDS

Astronomy education, lunar phase, augmented reality

Introduction

Observation, inference, critical thinking, and creativity are important skills for engineers. Students may think of the movement of celestial bodies and their interaction by observing the sun, moon, and stars, and then use scientific methods to induce the rules and causes of their movement. Thus, the observation and investigation processes can enhance their thinking and inference abilities. The moon is the closest celestial body to the earth, so it is a suitable target for observation in astronomy education for K12 students. For instance, students can realize the lunar phase is periodic by observing the movement of the moon in a regular and long-term manner, and they may also discover the relative motion of celestial bodies.

Observing the lunar phase requires long-term involvement, and it is difficult when facing the following situations: (1) a bad weather often upsets observation plans; (2) tall buildings in metropolitan areas may hinder observation; (3) impatient students may fail to keep complete records of lunar phases; (4) students may fall asleep when the moon appears late at night. Besides, it is difficult for students to infer that the lunar phase is regular and periodic from the recorded data. All these factors prevent them from developing correct lunar concepts.

Researchers have reported the success of computer simulation in supporting inquiry and reasoning skills (Dori & Barak, 2001; Chang & Sung, 2008). Some astronomy software provides easy-to-use graphic interface for simulating celestial phenomena, for example, Starry Night. The software enables us to observe the virtual sky and search for constellations from any location at any time. A few studies were focused on learning knowledge about lunar concepts by using simulation software. Tarng and Liou (2007) developed an astronomy museum for applications in elementary science education. Trundle and Bell (2010) studied the effectiveness of integrating simulation software with inquiry-based instruction to enhance the lunar concepts of pre-service teachers.

Although the available lunar simulation software is effective, a gap still exists between its operation and actual observation. Consequently, students may have difficulty applying their operational experiences to real observation, e.g., they don't need to know the azimuth and elevation angles when operating the simulation software on desktop computers. Moreover, the motion required in real observation such as raising hands in measuring the elevation angle and lifting heads in finding the moon is replaced by operating the mouse. Without physical operation and sensory integration, students may experience a hard time adjusting to outdoor observation.

As the advance of information technology, mobile devices such as personal digital assistants (PDA), smart phones, and tablet PCs are integrated into instructional applications. Hence, learning activities are no longer confined to classroom teaching, and they can be done anytime, anywhere and by using any devices to achieve the goal of ubiquitous learning (Harris, 2001). Mobile learning refers to any forms of learning which takes place when a learner is on the move or can move to a new place and still remain connected to online learning resources through wireless networks. Recently, a large number of mobile devices with powerful sensors such as GPS, electronic compass, and 3-axis accelerometer can provide the information of position, time, direction, acceleration, and so on to support the design of simulation software for applications in different areas of education.

Augmented reality (AR) is a view of the real world where elements are augmented by computer-generated situations or objects to enhance the perception of reality. In this way, the information in real environments becomes interactive and can thus be manipulated digitally and physically. Besides, artificial information about the environments and virtual objects can be overlaid in the real world. According to Azuma (1997), AR is an evolution of virtual reality (VR) with the following features: (1) interacting with real and virtual environments, (2) providing real-time feedback, and (3) must be in 3D space. Compared to the operation of VR, AR integrates a real environment with virtual objects to enhance one's comprehension and the sense of reality in a more interactive way.

In general, the implementation of AR can be categorized as: (1) the traditional AR, which requires a marker for positioning, e.g., the Magic Book (Billinghurst, Kato & Poupyrev, 2001), (2) the AR without a marker, in which positioning is done by GPS or image detection, (3) the AR combining a marker and image detection for positioning. This study is aimed at applying AR and mobile learning technologies to the moon observation by displaying the virtual moon on a mobile device when holding it towards the moon's direction. The main idea is to allow students to see the virtual moon even if the real moon is obstructed by a bad weather or tall buildings. Also, the data about lunar phases can be recorded for displaying the moon's track in the sky and the relative positions of the sun, earth and moon to enhance lunar concepts.

In 1970, the concept of context awareness was proposed by USA Department of Defense using GPS to obtain the user's location for providing various services (Schiller & Voisard, 2004). Its main idea is to satisfy the user's sensational requirement by updating necessary information according to environmental changes such as the current time and position (Schilit, 1995). The theory of situated learning (Brown et al., 1989) emphasizes that learning is unintentional and knowledge has to be presented in real situations. Its main idea is to provide a realistic environment for learners and the acquired knowledge can be applied in the same context. Therefore if learners wish to construct knowledge about lunar concepts, they should deal with the issues occurred in the real world. In this way, the obtained knowledge is more meaningful and can be applied in practical situations easily.

Based on the system of representation proposed by Bruner (1966), the initial phase of the cognitive process is enactive representation, where learners integrate actions into cognition in order to learn by doing. Moreover, they may turn the outside world into images, signs, and symbols to interpret the obtained knowledge in an abstract or a logical way. Hence, learners can understand and acquire knowledge easily and store it in long-term memory, which may enable learners to learn better in the future and develop the transfer of learning. According to relevant studies (Gardner, 1993; Hein, 1996), it was discovered that actions can attract learners' attention and enhance their learning. Thus, it is believed in this study that the integration of AR and physical operation in observing lunar phases can help students develop lunar concepts and store them in long-term memory to make learning more effective.

In this study, a lunar-phase observation system is developed using the AR technology and the sensor functions of mobile devices to help students observe and record lunar phases. When the user holds the mobile device towards the moon's direction, the screen will show the virtual moon overlapping with the real moon. The system allows the user to record the lunar phase and its azimuth and elevation angles as well as the date and time of observation. The system can shorten the learning process by setting different dates and times for observation, and it can solve the problem of unable to observe and record lunar phases due to a bad weather or tall buildings. In addition, the physical operation in observation can make a deeper impression for the user to store the obtained knowledge in long-term memory. A teaching experiment was conducted in an elementary school to investigate students' learning effectiveness by using the proposed system in learning lunar concepts. A questionnaire survey was conducted to analyse the attitudes of students after using the system, and the results can be used as a reference for improving the system.

System design

The moon observation system was developed under Microsoft Windows using the design tools of Shiva3D and 3ds Max. In addition, the tools of JDK, Android 1.5 SDK, Eclipse and Android Development Tool Plug-in were also required. After the completion of system design, ShiVa3D's Authoring Tool was used to convert it into the installation file (.apk) and published to the Android Market for users to download. The testing environment was Android 4.0.3 installed on an ASUS tablet PC. The system modules include: the 3D model of the sun, earth and moon, camera control and time control modules, user interface, GPS, electronic compass, 3-axis accelerometer, and the related API programs. The system can be executed on Android mobile devices. For educational applications, science teachers can download it from the Android Market and install on smart phones or tablet PCs for students to use.

The system is designed based on the learning topics of “Lunar Phase Observation” and “Sun, Earth and Moon” in K12 science and technology curriculum. The objective of the former is to realize the lunar phase is periodic by observing the movement of the moon in a long-term and regular manner; the objective of the latter is to discover the rising and falling of the moon and the lunar phase by the relative motion of the sun, earth and moon.

After entering the system, the user can see the main menu first, including the buttons of Observing Lunar Phase, Recording Lunar Phase, and Exit. The system is designed with five major functions: (1) locating the moon and displaying its lunar phase, (2) setting the system date and time, (3) recording the lunar phase, (4) displaying the moon track, and (5) showing the lunar phase according to the relative position of the sun, earth and moon. At the beginning, the system initialises GPS to obtain the data of current position, date, and time.

Locating the moon and displaying the lunar phase

The system uses an arrow to show the moon’s direction in the sky (Figure 1). As soon as the moon is located, a red circle will appear to surround it (Figure 2). After that, the user can click the Save button to record the lunar phase and its related data; the user can also click the Data button to check the recorded data. To prevent from pressing the Save button by accident, the system only records data when the moon is in the red circle. Also, it will show “Success” or “Failure” to inform the user if the moon is recorded successfully or not.

Figure 1: Showing the moon’s direction

Figure 2: Locating the moon within the red circle

Recording the lunar phase

By clicking the Save button on the main menu, the user can record the lunar phase hourly or daily and the system will record the lunar phase and the related data, including azimuth angle, elevation angle, date, time and position, accordingly (Figure 3). After recording the data, the user may convert them into organized and meaningful information by the functions of displaying moon track in the sky and showing lunar phases according to the relative motion of the sun, earth and moon to help the user understand lunar concepts.

Displaying the Moon Track

By clicking the button of Displaying the Moon Track, the system will show the lunar phases by the order of recorded time in one day (Figure 4). This function allows the user to see the different positions of the moon in the sky and the changes of its azimuth and elevation angles.

Figure 3: Lunar phases and the related data

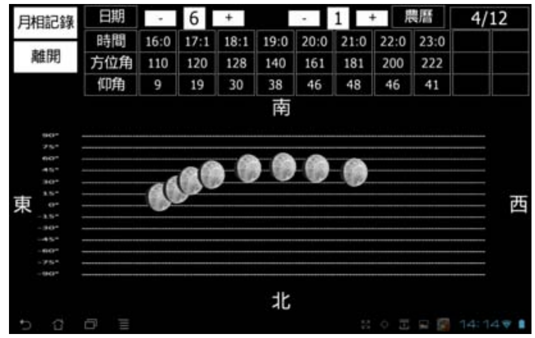

Figure 4: Displaying of the moon track in the sky

Setting the date and time

The user can change the system date and time by clicking the Date and Time buttons, and the current time can also be restored by clicking the Present Time button.

Cause of the lunar phase

The system has a built-in 3D model to simulate the relative motion of the sun, earth and moon, which can be used to illustrate the cause of the lunar phase. By clicking the Begin button, the system will apply the recorded data to the 3D model to demonstrate the cause of lunar phases with the perspective view from the outer space. After clicking the Play button, the system will show the relative positions of the three celestial bodies and the corresponding lunar phase.

Teaching experiment

In this study, a teaching experiment was conducted to investigate the learning effectiveness of students by using the moon observation system to learn lunar concepts. Two classes of 4th graders in an elementary school in Taichung were randomly selected as experimental samples, one as the experimental group (27 students) and the other as the control group (29 students). This study used the “non-equivalent groups pre-test and post-test” design to analyse if the proposed system could enhance the learning effectiveness of lunar concepts. In the experiment, the independent variable was the teaching method; the covariant was students’ ability about lunar concepts before learning; the dependent variable was their ability about lunar concepts after learning; the control variables were the teacher, instruction time, and learning contents. A questionnaire survey was conducted to analyse the attitudes of experimental-group students after using the system, and the results could be used as a reference for improving the system in the future.

Before the teaching experiment, all students (the experimental group and control group) took the pre-test. Then, they began to observe the moon for a whole month. The experimental group used the moon observation system developed in this study; the control group adopted the traditional observation method and recorded lunar phases on a worksheet. After the teaching experiment, both groups took the post-test to see if using the moon observation system could achieve better learning effectiveness than using the traditional method. A questionnaire survey and interviews were further conducted to investigate the attitudes of students after using the system. The data collected in this experiment includes: (1) the pre-test scores, (2) the post-test scores, (3) the questionnaire results, and (4) the observation and interview data from the experimental group. Finally, the achievement test scores were analysed by the independent samples T-test, paired samples T-test, and ANCOVA; the questionnaire results were processed by descriptive statistics.

Learning Achievement

In order to verify that the abilities of lunar concepts for the two groups were about the same prior to the experiment, an independent samples T-test was conducted to analyse their pre-test scores. Before that, the assumption of the homogeneity of variance had to be met, so they were analysed by a Levene's test and the results show that f=1.853 and the significance p=0.179>0.05, which does not achieve the standard of significant difference and thus conforms to the homogeneity of variance. After applying the independent samples T-test to analyse the pre-test scores of the two groups, the t value is computed as 0.406 and the significance p=0.686>0.05, which is higher than the standard of significance difference. In other words, the pre-test scores for both groups had no significant difference and their abilities in lunar concepts were about the same.

This study adopted the paired samples T-test to examine if the experimental group made significant progress in learning lunar concepts. According to the results in Table 1, the average pre-test score of experimental group is 40.89 and the average post-test score is 48.44. The t value is computed as -2.72 and the significance p=0.011<0.05, indicating that the experimental group had made significant progress after using the moon observation system for learning lunar concepts.

Table 1: Paired samples T-test of the experimental group

Score	Mean	S. D.	Progress	T value	Significance
Pre-test	40.89	13.83	7.55	-2.72	0.011*
Post-test	48.44	14.09			

This study also used the paired samples T-test to examine if the control group made significant progress in learning lunar concepts. According to the results in Table 2, the average pre-test score of control group is 38.62 and the average post-test is 39.17. The t value is computed as -0.24 and the significance p=0.812>0.05, indicating that the control group did not make significant progress by using the traditional method to observe the moon for learning the lunar concepts.

Table 2: Paired samples T-test of the control group

Score	Mean	S. D.	Progress	T value	Significance
Pre-test	38.62	16.81	0.55	-0.24	0.812
Post-test	39.17	17.90			

Before conducting the ANCOVA, it is required to meet the assumption of the homogeneity of variance and within-group regression coefficient. This study used a Levene's test to analyze the homogeneity of variance and the results show that the significance p=0.984>0.05, satisfying the assumption of the homogeneity of variance. As for the homogeneity of within-group regression coefficient, the significance p=0.157 is higher than the significance standard of 0.05. In other words, there is no significant difference between the two groups' slopes of regression coefficient and thus the ANCOVA can be conducted to see if a significant difference exists in learning effectiveness between the two groups.

The ANCOVA results are shown in Table 3 where the value of f=5.32 and the significance p=0.025<0.05, indicating a significant difference exists between the two groups after the experiment. Since the mean of the experiment group's progress score is 7.55 and that of the control group is 0.55, it can be inferred that the experimental group performed better than the control group in learning lunar concepts.

Table 3: The ANCOVA results for learning effectiveness

Source	S. S.	D. F.	M. S.	F	Significance
Group	834.57	1	834.57	5.32	0.025*
Error	8313.44	53	156.86		

Questionnaire Results

A questionnaire survey was conducted to investigate the attitudes of students after using the moon observation system, and the results (the average score of the 5-point scale is noted by S) are summarised in the following:

Basic information

Regarding the frequency of using the system, 60% of the students observed the lunar phase once or twice a day; 25% of the students conducted observation at least 5 times a day. As for the time spent on observation, most students spent less than 10 minutes per day and 50% of the students spent less than 5 minutes, indicating the students used the system frequently without spending too much time.

Ease of use

Most students agreed that "The user interface is easy to understand" (S=4.6) and "Learning to operate the system is easy" (S=4.6). A few students didn't know how to use the arrow head to locate the moon at the beginning. Some other students suggested that it would be more convenient if the system allows them to connect to the Internet for obtaining information about the lunar phase and writing down their feedback for discussion.

Usefulness

Most students agreed that "The system helps me record lunar phases" (S=4.55) and "The system is useful to search for the information about lunar phases." (S=4.55). Besides, they thought the system is more helpful in distinguishing the first quarter moon from the last quarter moon.

User's attitudes

Most students agreed that "I like to use the system to observe the moon" (S=4.6) and "I consider it worthwhile to observe the moon using the system" (S=4.55). Most students were impressed by the instant display of the lunar phase, and they considered it useful to observe the moon using the system. Since the system can be used indoors, they thought the observation is not affected by the weather.

Willingness to use the system

Most students agreed that "I will use the system if I have to observe and record lunar phases" (S=4.65) and "I will consider using the system first when needed" (S=4.45). Compared with the traditional observation method, students would like to use the system for learning because in the past they could only obtain knowledge from textbooks and now the observation can be done at any time and any place. In addition, the azimuth and elevation angles can be recorded easily without using a compass or elevation observer.

Findings in the Experiment

Since the control group used the worksheet for recording the lunar phases, some students were bored when the teacher was explaining the details about how to record the data of lunar phase on the worksheet. Consequently, they were not familiar with the way of recording the lunar phase and thus made a lot of mistakes. The experiment group were interested in operating the system and they could not wait to raise tablet PCs to locate the moon before the teacher finished the instruction. Moreover, they interacted with each other frequently and were very active in asking questions during the class.

To verify the accuracy of students' observation records, this study consulted Taipei Astronomical Museum for the azimuth and elevation angles of the moon at 8 p.m. on June 1st, and they were 158.5 degree and 47.5 degree, respectively. Figure 5 shows the lunar phase data recorded by Student A from the control group (left) and by Student B from the experimental group (right). It can be seen that the azimuth and elevation angles recorded by Student A were both wrong. Moreover, he could not draw the correct track of the moon in the sky. It is possible that Student A did not use a compass to measure the azimuth and elevation angles correctly. Before the bedtime, he could only draw three lunar phases on the worksheet, which was not enough to show the complete moon track in the sky. The data recorded by Student B were made by the system to show the detailed information about the lunar phase in each hour, including the date and time on the general and lunar calendars, azimuth angle and elevation angle. Besides, the moon track in the sky is shown clearly, so it was expected that students in the experimental group could learn correct lunar concepts more easily by keeping correct and complete data of the lunar phases.

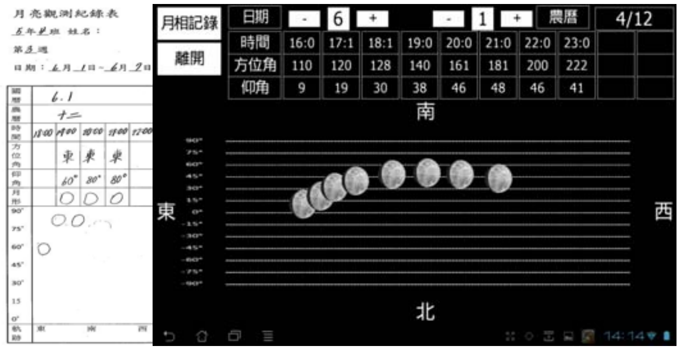

Figure 5: The observation data recorded by the students both groups

To realise how the system could help students collect data about lunar phases, the statistics of observation days by both groups are shown in Table 4 where the average observation days for the experiment group is 17.8, with the minimum of 5 days and the maximum of 27 days. On the contrary, the average number of observation days for the control group is 4.6, with the minimum of 0 day and the maximum of 8 days. On average, the control group observed the lunar phase about once a week, and two students didn't conduct observation at all.

Table 4: Table Statistics of observation days for both groups

Group	Students	Minimum	Maximum	Average
Experimental	27	5.0	27.0	17.8
Control	29	0.0	8.0	4.6

A comparison of observation records kept by experimental and control groups can be found in Table 5. The average number of records for the experimental group is 48.9, with the minimum of 6 records and the maximum of 285 records, indicating the observation records were kept at least once a day. On the other hand, the average number of records for the control group is 5.5, about once per week, and half of the control group students kept no more than 5 records, and, what's worse, there were three students without keeping any records at all.

Table 5: Statistics of observation records for both groups

Group	Students	Minimum	Maximum	Average
Experimental	27	6.0	285.0	48.9
Control	29	0.0	14.0	5.5

Conclusions

Recently, mobile and augmented reality technologies have been popular among education research. This study could be a helpful reference for engineering teachers who want to design mobile instruments assisted learning in authentic environment. In this study, a moon observation system is developed using the AR technology and sensor functions of mobile devices to help students observe and record lunar phases. A teaching experiment was conducted to analyse students' learning effectiveness. The results of achievement test showed that the learning effectiveness of the experimental group is significantly better than that of the control group. The questionnaire survey and interview results revealed that most students preferred to use the system for moon observation. They considered the system useful in terms of locating the moon and recording the data of lunar phases. In addition, most students agreed that the system is easy to operate, and they would like to use it again if they have a similar requirement.

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Acknowledgements

The authors would like to thank for the financial support of the National Science Council (NSC), Taiwan under the contract number NSC 102-2511-S-134-009.