Development and Educational Practice of a Lunar Observation Support System by using Mobile Phones for Science Education

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Abstract
A Lunar Observation Project that utilizes mobile phones was undertaken with junior high school students as the subjects. A “Lunar Observation Support System” that can be used with mobile phones was developed. Using this system, students observe the Moon in the open air and send observational data through their mobile phones to the server; the server automatically stores the data in a database. The system also possesses a Computer-Supported Collaborative Learning (CSCL) feature through which students can share observational data with each other and engage in discussions. From a practical study, we found that students were able to send lunar observational data from their mobile phones effortlessly from the outdoors, and their interest, attention, attitude, and motivation toward nature observation improved. In addition, sharing each student’s observational record on the Web Database and engaging the students in discussions led to the correction of simple false beliefs that students often have, such as “the Moon can be seen only during the night” and “the Moon rises at the same time everyday.”

Key Words: u-Learning, Mobile Phone, CSCL, Web Database, Observational Studies, Science Education

1. Introduction

In Japanese education, growth of science communication among various people is an urgent need. Ministry of Education, Culture, Sports, Science and Technology has struggled to enhance science communication among various people, involving elementary, junior high and senior high school students, college students, graduate students and experts (Ministry of Education, Culture, Sports, Science and Technology, 2006) [1]. The Science Council of Japan, moreover, has stated that it is necessary to foster science communicators, including prospective teachers and science volunteers (The Science Council of Japan, 2007) [2]. To contribute toward mitigating this social issue in Japan, authors have focused on the moon as a popular scientific topic in astronomy.

It is not easy for both children and adults to communicate about astronomical phenomena. Many investigators have examined students’ ideas of the relationships among the moon, earth, and sun (for example, Vosniadou and Brewer, 1994; Agata, 2004) [3] [4]. Prospective elementary school teachers frequently hold similar problematic conceptions of cosmic relationships (for example, Atwood & Atwood, 1997; Suzuki, 2003) [5] [6].

On-going observation and conversation have the possibility of enhancing college students to understand the phases of the moon (Suzuki, 2003). In another research (Suzuki, et al., 2006), most of students seemed to value the experience of making observations, sharing observational data and developing explanations of the moon. Some, however, showed resistance to recording and observing the moon outside the classes, and that they couldn’t do this, even though they realized that observations of the moon would be useful for learning about the moon [7]. Reasons could be awkward to write down observational records on paper in the field and; there are differences among individuals’ writings of the same moon.

Authors developed the LOS system consists of a mobile part and a sharing part on PCs to facilitate students’ ability to continue observation of the moon, to share observations and to converse about them. Using the LOS system, users observe the moon in the open air and send observational data through their mobile devices to the server; the server automatically stores the data in a database. (Miyata et. al., 2007; Suzuki et. al., 2007) [8] [9].

Personal, portable, wirelessly-networked technologies have created the potential for a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different environments. Many education support systems by ubiquitous access to mobile, connected, personal, handhelds have been developed (Chan, et al., 2006) [10]. Ways to use movable devices such as a PDA and a mobile phone for fieldwork and project based learning have been examined. For example, the collect system by O’Hara, et al. (2007) consists of a mobile application, a series of situated signs and a personalized web page [11]. Haapala, et al. (2007) studied parallel collaborative learning
between students in the classroom using a PC computer and students in the field using a mobile device [12]. In Japan, Takenaka, et al. (2006) developed the sharing information system on a website by sending pictures taken with mobile phones as e-mail attachments [13]. These studies examined the effects of systems which provide users observing frameworks through mobile devices and/or collect user’s observational data for sharing.

The LOS system possesses two features; 1) a scaffolding feature to enhance users’ deliberating on the phases of the moon and 2) a CSCL (Computer-Supported Collaborative Learning) feature through which users can share observational data on PCs with each other and engage in discussions.

We did two practices for 10 junior & senior high school students (Miyata, et al., 2007) and for 15 college students (Suzuki, et al., 2007). In the study for 10 junior & senior high school students, they observed the moon, interacted mainly with an on-line facilitator and shared the observational data with other participants via internet. The study for 15 college students was implemented in a part of a course for prospective teachers. They observed the moon out of the classroom and also communicated with each other in the classes. In this paper, we discuss about both the junior & senior high school course and university course to evaluate the LOS system, when incorporated into fieldwork and project based learning inside and outside of a classroom.

2. Objective of this Research

We developed a “Lunar Observation Support System” that utilizes the capability of mobile phones to access the Web and in which students can submit observational data of the Moon. We also developed a Web-based educational material entitled “Moon Observation Project” in which the uploaded observational data is automatically stored in a database and can be viewed in real time. The objectives of this research are to validate and analyze the usability of the Lunar Observation Support System as a learning tool and to understand whether by using the tool and employing junior and senior high school students as subjects, there are any effects on the students in nature observation classes; in particular, we study their knowledge, understanding, thinking, judgment, interest, attention, attitude, and motivation with regard to the study of the Moon.

3. Research Method

We analyzed the effectiveness of the Lunar Observation Support System by employing students from grade 1st of junior high school to grade 1st of senior high school as subjects and by using data collected from a nature observation class that utilized the system. In particular, we validated and analyzed the effect of utilizing the mobile phone for recording lunar observations on the students with respect to changes in their knowledge, understanding, thinking, judgment, interest, attention, attitude, and motivation.

3.1. Subjects

The subjects comprised students from grade 1st of junior high school to grade 1st of senior high school (8 boys and 2 girls)

3.2. Orientation for lunar observation and the investigation process

We explained the usage of the Moon Observation Support System on December 9, 2006 at Shiga University using handouts. In addition, in order to investigate the students’ knowledge of the Moon before beginning the observations, we administered a test entitled “Survey on the Appearance of the Moon,” which was based on the Lunar Phases Concept Inventory (LPCI).

3.3. Observation period

The observation period was from December 9 to December 30, 2006 (approximately 3 weeks or 22 days).

3.4. Notes on data collection and analysis

3.4.1. Lunar Phases Concept Inventory (LPCI)

LPCI is a survey questionnaire comprising 20 multiple-choice questions concerning the phases of the Moon. The survey was developed by Lindell et al [14]. According to Lindell et al. (2002), the survey is suitable for analyzing the conceptual knowledge that university students have on lunar phases. Since the accuracy rate for LPCI is not high even for university students, we selected 11 questions out of the 20, taking into consideration the fact that junior and senior high school students will be answering these questions. The test based on LPCI and entitled “Survey on the Appearance of the Moon” was administered before the observation period began, and it was administered again after the three-week observation period as a post-observation survey.

3.4.2. Paper-based questionnaire

At the end of the three-week observation period, we asked the students to complete a questionnaire that consisted of 14 three-choice and four-choice questions and a free-text question. The questionnaire was designed to elicit the students’ opinions on the use of a mobile phone for entering observational records and on viewing the records using a PC as well as on the usability of the Web site of the Lunar Observation Support System for mobile phones.

4. Structure and Content of the Lunar Observation Support System

4.1. Lunar Observation Support System for mobile phones (http://mb.cerp.shiga-u.ac.jp/moon/m/)

The present system comprises the Web site entitled “Lunar Observation Support System,” the administrative interface for downloading the submitted data, and the database server in which the data is stored.

The Web site consists of the following pages:
“Top page (Fig.1),” “Enter observational record, (Fig.2),” “Select the phase, (Fig. 3)” “Adjust the slant and phase,” “Confirm selection and enter observational note,” and the “Submission complete”.
In the “Adjust the slant and phase” screen shown in Figure 4, a large graphic of the Moon with the selected phase is displayed, and the user can increment or decrement the slant in 15° intervals up to 90°. The user adjusts the slant of the Moon to the angle closest to his/her observation. Further, the user can finely adjust the phase of the Moon, which was selected in Figure 3, while looking at a larger image of the Moon. After all the adjustments have been completed, the user clicks on the “Next” button and proceeds to the “Confirm selection and enter observational note” page.

4.2. Web-based Educational Content

(http://db.cerp.shiga-u.ac.jp/moonwatch/kansatsu1.htm)  
(http:// db.cerp.shiga-u.ac.jp/moonwatch/kansatsu2.htm)

The records of lunar observations submitted by the students are saved automatically in a database on the server, and they can be viewed as a list of observational records on the Web site as the observational lists.

4.2.1. Observation List #1 (sorted by observation time)

As shown in Figure 5, “Observation List #1 (sorted by time)” displays the observational records that are stored on the database and sorted by the observation time. In this view, there is a functionality to “search and filter” records according to various conditions. For example, entering the keyword “Full Moon” and clicking on the “filter” button will extract and display only those records that have the keyword “Full Moon” in the observation notes. In addition, the user can sort the submitted observational records by the lunar phase or name of the group. The sorting can be cancelled by clicking on the “cancel” button.

4.2.2. Observation List #2 (two-dimensional display)

The “Observation list #2 (two-dimensional display)” page shown in Figure 6 displays the observational records with the observation date on the vertical axis and the observation time on the horizontal axis. The only information displayed in this view are the pictures of the Moon; however, if a person clicks on a picture of the Moon, the list of detailed observations is displayed on a separate window in a card format. The pictures of the Moon are stacked, and if there are more than two submissions for the same time window, then the top picture is labeled “first” and up to 5 other pictures that are layered in the order of the observed time can be displayed.
5. Architecture and Implementation of the system

5.1. Architecture of the system

The architecture of the web-based Database system is shown on Figure 7. As can be seen from the Figure 7, the architecture is classical client-server architecture, providing different communication ways between the client and the server. The server includes the database, PHP module and web-server. The web-server communicates with the database in both directions over the PHP module. The client sends a request to the server, so server accepts that request and sends back the requested data to the client. The received data by the server are processed to new-web page. The client-server communication for Pocket PC can be via Wireless LAN, based on the 802.11b standard. The mobile client communicates with server via GPRS Internet [15][16][17][18].

5.2. Implementation of the system

For full functionality, this system requires server and client. The server side contains database with some stored procedures and functions developed in Oracle 9.2i, and a web server Apache which is an integral part of Oracle 9.2i. The web server contains the source code of the web based application developed with PHP 5 together with HTML using the Macromedia Dreamweaver MX 2004.

One of the Clients on Figure 8 is Pocket PC which works on Windows CE platform and uses Internet Explorer. The communication between client and server is typically via wireless Internet. The Pocket PC has integrated wireless card and communicates with web based application via access point. The setting of the Pocket PC for this communication must be appropriate, and the user must have enabled entrance to the access point.

The Second Client in this case is Mobile phone which works on Symbian OS platform and uses Opera Web browser. The communication between client and server is typically via GPRS Internet. The setting of the Mobile device for this communication must be appropriate and the user must have enabled a GPRS service by the mobile operator. For correct display of the Cyrillic characters on the Opera browser, on the Preferences the encoding must be set to "Cyrillic (Windows-1251)".

6. Results and discussions

6.1. Accuracy rate of the LPCI before and after the observation (the junior & senior high school students)

The study of Suzuki et al. (2006), mentioned earlier in this document, reported the result of the same LPCI (20 questions) that we used; the test in their study was administered to university students as a survey preceding lunar observations. They reported that the accuracy rates for questions 1, 5, 7, and 9 (about Lunar Phases) were extremely low. As can be predicted from this report, the accuracy rate for questions 1, 5, 7, and 9 in the pre-observation survey of the 10 junior and senior high school students were lower when compared to the accuracy rates for the other questions. The accuracy rate for question 10 was also low. In the study by Suzuki et al. (2006), however, the survey resulted in a relatively higher accuracy rate for question 10. It should be noted that question 10 dealt with “spatial positions of the Sun, Moon, and Earth,” and we believe that the difference in the score between the university and the junior/senior high school students was due to the fact that the latter have lesser ability to picture in the mind and simulate the relative positions of the Sun, Moon, and Earth when compared to university students.

Further, in the post-observation survey following the three-week period of observing the Moon, the accuracy rate declined only for questions 5 and 8, and the accuracy rate for all the other questions remained unchanged. As mentioned previously, question 5 had a very low accuracy rate as students not only had to take into consideration the perceived motion of the Moon but
also required knowledge of the Earth’s spin; therefore, it was difficult to answer correctly. Further, question 8 was to be solved using a three-dimensional approach in which the observer looked down into space from the top of the Earth to observe the Moon, and therefore it proved to be a difficult question. Since both questions 5 and 8 were difficult to answer correctly for junior and senior high school students, it is difficult to determine whether the students who correctly answered these questions during the pre-observation investigation properly understood the question or were simply answering instinctively through trial and error. The above explanation provides the reasons for the accuracy rate for these two questions not improving.

6.2. Change in the accuracy rate of LPCI for individual students (at junior & senior high school)

Figure 8. Implementation of the Web-based Database system

Figure 9 shows the change in the LPCI accuracy rate for each student. The accuracy rate for the post-observational survey improves as compared to that before the observation for five out of the eight students. On the other hand, the accuracy rate declines for three of the students. To understand the relationship between the change in the accuracy rate and the number of lunar observations submitted, we made the assumption that the number of submissions is equal to the number of observations made. With regard to students G and H, although their score in the pre-observational survey was not particularly high, their accuracy rate significantly improved in the post-observational survey. In particular, student G scored the highest accuracy rate despite being a second-year junior high school student. It is apparent that within the short period of three weeks, the students’ own observational activities and hints obtained from viewing the list of records on the Web-based educational content had a significant effect (as in the case of G and H) in increasing their knowledge and understanding of the appearance of the Moon. Specifically, the “hint” obtained from the Web-based content refers to the window of time in which the Moon can be observed and the shape and slant of the Moon, which were key parameters in the lunar observations.

Figure 9. The change in the LPCI accuracy rate for each student

In addition, we believe that student F, whose the accuracy rate in the post-observation test declined despite the number of submissions not being small, was unable to obtain any new knowledge from the observational activity or increase his/her understanding through the Web-based educational content and the list of observational records. Student F is a first-grade junior high school student and is the youngest among the participants. Thus, it can be deduced that student F was not choosing the correct answers by understanding the questions during the pre-observation survey, but was answering these questions.
rather instinctively through trial and error; this led to the decline in the student’s accuracy rate in the post-observation survey.

Further, as shown in Figure 10, a correlation coefficient of 0.467 was obtained between the increase in the number of correct answers and the number of submissions, which is not statistically significant. This value, however, represents a moderate positive correlation, and we can observe that with regard to the subjects employed in this investigation, there is a tendency for students who posted a larger number of submissions to have a larger increase in the number of correct answers.

When the responses were analyzed as percentages, it was found that all items were positive evaluation about this system. No one selected “strongly disagree” and “disagree” for all items of questionnaire. This indicates that the usability of this system was comfortable for students.

6.3.2. Evaluation of the Web-based database system “List of Observational Records”

There were four students who commented on the ease of viewing the list of observational records on the Web; they provided answers such as “it was easy to view (the records) in a batch.” Further, it was apparent that by displaying the observational records in two dimensions according to the date and time, it was easy to not only view the records but also think about and decide on the time window for observing the Moon (see Figure 6). The list of observational records is a collection of not only a single student’s records but also those submitted by other participants. One student’s record is only a point on the timeline, but a collection of observational records submitted by multiple students forms a band of accumulated data on the time axis. This made it possible for students to predict the time window, based on the observational records of the other participants, for observing the Moon the next day. As seen from these comments, it can be stated that the system functioned as a tool for promoting the sharing of knowledge by allowing each student to leverage each other’s knowledge as observers. In addition, while it is also possible to create a list of observational records on paper, this would require all observers to bring their records to the same physical location. All the participants will also need to gather at the same location to view the list of compiled observations written on paper. However, using the present system, the students can view the information from any PC connected to the Internet, at any location (from home or school), and at any time. This significantly facilitates knowledge sharing.

Similarly, while two-dimensional observational records can be recorded on paper, if the students are to manually draw pictures of the Moon, there is a possibility that the shape of the Moon would vary from one student to another. By showing the same picture of the Moon on the Web, the observational record will have lesser degree of individual differences. Thus, it can be stated that the present system using a mobile phone in conjunction with a PC is more effective than paper-based media in listing the observational records of lunar observations. From the abovementioned reasons, we believe that the use of the present system led to increased thinking, interest, attention, and motivation in addition to better attitude with regard to the study on the Moon in the junior and senior high school student participants.

6.3.3. Analysis of the free-text responses

In response to the question, “Please write freely about what you thought or felt when participating in the
Moon Observation Project,” student F responded, “I was surprised that (the Moon) could be seen at a much earlier time of the day than expected”; this answer indicated that the simple false belief that the student held with regard to the time band in which the Moon can be observed was corrected. There was also an opinion by student G who wrote, “I thought I knew the Moon well; however, after recording some observations, I realized that there are many things that I do not know or understand,” and it appears that the students were able to feel that there are many uncertain facts that are not known until a person becomes involved in actual observations, even for those objects that are familiar.

As commented by student D who wrote, “I understood that full Moon occurred approximately once every month,” there were students who wrote explicitly on the knowledge that he/she gained through the project. It can be observed that the students were self-aware of the knowledge and understanding on the Moon that were gained through their participation in the project.

In addition to the above, there were six students who commented on the satisfaction that they felt from participating in the project, including student I who wrote, “I would not have looked at the Moon if it were not for such a project; it was a good experience” and student J who wrote, “It felt very good to be a part of this project.” It is clear from these comments how the students were distanced from experience-based learning in their everyday lives.

6.4. Survey on the evaluation of this system at the university

6.4.1. Course Practices for university students

The practices were implemented in a part of a course of pre-service education from October in 2006 to January in 2007 at Shiga University. This course was one of the required courses to earn a license for becoming junior and senior high school science teachers. Participants were 15 prospective teachers, one instructor, 2 teaching assistants and 2 technical supporters.

After the course orientation and explanation of ways to observe the moon, the students were divided into two groups (7 or 8 in each group). One group used the LOS (Lunar Observation Support) system, and the other used paper as an observational tool & a data sharing tool. They observed the moon, recorded their observations, brought and shared the observational data with colleagues of the group, and communication with each other. After four weeks of observation, the groups exchanged procedures. All kept observing the moon for another four weeks. In classes during the first four weeks, the students shared observation data in the group. The group with the use of the LOS system watched the observation lists provided by the system. The group with the use of the paper sheets pasted the observation sheets on the large paper sheet with each other. After that, the students in each group were divided into three small groups (2 or 3 in each small group). Each small group discussed about the observational data and wrote down what they had made sense, solved tasks provided by the instructor, and created teaching tools to enhance learners’ understanding of the mechanisms of the phases of the moon. For the last four weeks they just shared observation data within each group, communicated with one another and wrote notes in each small group.

6.4.2. Students’ Evaluation of Practices

Most of students evaluated on-going observation and communication inside and outside of a classroom positively. Based on the students’ responses to the questionnaires about the practices, 90% of students thought fieldwork, observation of the moon outside the classes, was “very good” or “good.” 93% answered positively about communication of observational records inside the classes.

6.4.3. Moon Observation Frequencies

The LOS system could encourage students to continue observation of the moon. The Table 1 shows the average of the moon observation frequencies with the use of LOS system and paper sheets. The observation frequencies using the LOS system are bigger than paper sheets’, even though there is no statistically significance. This result is similar to the finding in previous research (Suzuki et al., 2007, [9]) that many students responded to a questionnaire that they would choose the LOS system rather than paper sheets as an observation and data sharing tool.

<table>
<thead>
<tr>
<th>Table 1. Average of the moon observation frequencies</th>
</tr>
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<tbody>
<tr>
<td>With the use of LOS system</td>
</tr>
<tr>
<td>With the use of paper sheets</td>
</tr>
</tbody>
</table>

6.4.4. Deliberation on the Moon Phase

It is inferred that the LOS system could facilitate students to deliberate the age of the moon while choosing and adjusting the phase through mobile phones. Just after first discussions about the observational data in the classroom, the term “the age of the moon” appeared only in notes by two small groups who used the LOS system in the field. This result is similar to a typical positive description about the use of the LOS system for mobile phones by a student in the prior research (Suzuki et al., 2007, [9]): “(I) could record the exact age of the moon” (NM).

6.4.5. Change of the Accuracy Rate of LPCI

On-going observation of the moon in the group and communication about the shared data with each other of the small group would enhance prospective teachers’ understanding the concepts of the moon. It would be effective especially for the students who initially have less knowledge about the moon.

The average of all students’ accuracy rates increased from 62.67% pre observation to 71.40% just after four weeks observation (p < .05) and to 77.99% just after eight weeks observation (p < .01). Fig. 12 represents the individuals’ accuracy rate of LPCI. The accuracy rate...
for the post1 (four weeks observational survey) improves as compared to that before the observation for 12 out of 15 (80%). The accuracy rate for the post2 (eight weeks observational survey) improves as compared to that before the observation for 12 out of 15 (80%).

In Figure 12, each student is identified by the number of small group such as “G1” or “G2” and the code of individual such as “Y” or “S.” G1, G3 and G5 used the LOS system for four weeks, and then the paper sheets for another four weeks. G2, G4, G6 did in reverse.

According to the Fig. 12, we could realize that the students, who had lower accuracy ratio before the observation of the moon (G5H; 40, G2T; 35, G4MU; 30), increased their ratio dramatically after eight weeks observation. This tendency was defined by correlation coefficient between change of accuracy ratio from pre to post2 inventory and the first accuracy ratio as a pre investigation ($\rho = -0.856$).

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6.4.6. Change of the Accuracy Rate of Three Categories of LPCI

When solving the more difficult questions with the use of the three dimensional imagination, on-going observation and communication has a possibility to help the students’ thinking and understanding the concepts of the moon.

The authors grouped 20 questions of LPCI into three categories named “A,” “B,” and “C.” When solving the questions in A (No.1, 9, 10, 14, 15), students need to use knowledge based on the observation and imagine the relationships among the moon, earth, and sun three dimensionally. In solving questions in B (No.2, 5, 8 12, 17), it is necessary to use knowledge based on the observation. While solving questions in C (No. 3, 4, 6, 7, 11, 13, 16, 18, 19, 20), students use the astronomical knowledge not relating to the observation of the moon. The questions in A are the most difficult in the LPCI’s questions.

Table 2 shows the average of all students’ accuracy ratio per each group of LPCI. The ratio of pre survey shows the questions in A would be more difficult to be solved, comparing to questions in B & C. After eight weeks observation, the accuracy ratio of group A improved as compared to that before the observation. Also, both of four & eight weeks observation, the accuracy ratio of group C improved as compared to that before the observation. These findings reinforce the conclusion that the more students observed the moon, the more they could demonstrate understanding the moon’s phases.

Table 2. Average of accuracy ratio in each group

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post1</th>
<th>Post2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>42.67</td>
<td>56.00</td>
<td>61.33*</td>
</tr>
<tr>
<td></td>
<td>(SD = 21.20)</td>
<td>(SD = 18.82)</td>
<td>(SD = 17.67)</td>
</tr>
<tr>
<td>B</td>
<td>66.67</td>
<td>73.33</td>
<td>80.00</td>
</tr>
<tr>
<td></td>
<td>(SD = 33.52)</td>
<td>(SD = 24.69)</td>
<td>(SD = 15.12)</td>
</tr>
<tr>
<td>C</td>
<td>70.67</td>
<td>84.67 **</td>
<td>83.33 **</td>
</tr>
<tr>
<td></td>
<td>(SD = 33.52)</td>
<td>(SD = 12.46)</td>
<td>(SD = 14.47)</td>
</tr>
</tbody>
</table>

* < .05 ** < .01

6.4.7. Moon Observation Frequencies and Change of the Accuracy Rate of LPCI during Four Weeks

We realize that it is necessary to develop an additional function of the LOS system, in order to encourage students to activate conversations about their own observation records stored by the LOS system.

Figure 13 and Figure 14 show moon observation frequencies and change of accuracy rate of LPCI of individual student during four weeks, respectively in the group who used the LOS system and the paper sheets. White circle represents ratio of pre observation and black one represents that of post1 (four weeks observational survey).

According to Figure 13 & Figure 14, the students who changed most in each group were G5A (60 to 85) in the LOS system usage group & G2T (35 to 90) in the paper sheets usage group. Table 3 shows the individual observation frequencies and the accuracy ratio of post1 in the small groups G5 and G2. The accuracy ratio of Post1 of G2’s members is higher than G5’s and also all members’ in G2 is same.
The other hand, the accuracy ratio of members in G5 is spread, comparing to G2’s. In addition, G5T who had had the lower accuracy ratio before observation got the highest ratio after four weeks observations, even though the observation frequency of G5T was low. Members in G2 had to paste the observation sheets on the large paper sheet with each other to share their observational data in classes. It is inferred that while pasting the sheets, members in G2 communicated so much that they shared their ideas about the moon, besides their observation data. Meanwhile, it was not necessary for members in G5 to take time for sharing their observational data by themselves in classes, because of the usage of the LOS system.

<table>
<thead>
<tr>
<th>Observation frequencies</th>
<th>G5T</th>
<th>G5A</th>
<th>G5H</th>
<th>Accuracy ratio of post1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>15</td>
<td>34</td>
<td>G5T</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>17</td>
<td>19</td>
<td>G2T</td>
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<tr>
<td></td>
<td>70</td>
<td>85</td>
<td>50</td>
<td>G2T</td>
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<tr>
<td></td>
<td>92</td>
<td>90</td>
<td>90</td>
<td>G5A</td>
</tr>
<tr>
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<td>92</td>
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7. Conclusion and Future Work

We have undertaken a Lunar Observation Project utilizing mobile phones and with junior and senior high school students as subjects for investigation. We developed the Lunar Observation Support System using which students could observe the Moon in the outdoors and submit observational data from their mobile phones to the server. The system has a CSCL functionality in which the submitted data is automatically stored in a database on the server, and each student can share his/her observational records and participates in discussions. The result of a practical study showed that the students were able to send the observation records of the Moon from outdoors with ease, and the students’ interest, attention, attitude, and motivation toward the observation of nature improved. On the basis of a paper-based questionnaire that was administered after the observation period ended, it became clear that the students viewed the observational records on the Web-based educational content with clear objectives such as “I would like to know when the Moon will rise tomorrow” and thereby developed the thinking and judgment skills required for predicting the time band for observing the Moon. The sharing of their observational records on the Web-based database and the holding of discussions led to the correction of some simple false beliefs regarding the Moon, such as “the Moon can be seen only at night” and “the Moon always rises at the same time.”

There is our intention to revise learners’ partial understanding about the moon by sharing their observational data. Some data were correct, but some data were incorrect. So, learners were discussing about incorrect data by using the comment card system.

In terms of practices, most of students evaluated on-going observation and communication inside and outside of a classroom positively. The LOS system could encourage them to continue observation of the moon. The system, moreover, could facilitate students to deliberate the age of the moon while choosing and adjusting the phase through mobile phones. The detailed analysis about students’ conceptions of the moon shows the possibility which on-going observations, sharing observational data and communicating with each other facilitate college students to understand the concepts of the moon. It would be effective especially for the students who initially have less knowledge about the moon. Moreover, even though the questions are not easy to be solved, on-going observation and communication has a possibility to help students’ thinking & understanding the concepts of the moon.

The other hand, the authors realize that it is necessary to develop an additional function of the LOS system, in order to encourage students to activate conversations about their own observation records stored by the system. Moreover, accuracy ratio of questions in A of LPCI was 61.33 % as the last inventory. It must be hard to think and imagine the relationship among the moon, earth and sun three dimensionally, even for college students who want to become junior high & senior high school science teachers. Therefore, we think that it is necessary to add a new function of the LOS system to facilitate students imagine that three dimensionally.

Considering that it takes a long time to gain knowledge and understanding of the appearance of the Moon as well as to avoid the effect of bad weather on the number records, this research study needs to carry out more detailed investigations by increasing the observation period.

Further, it is conceivable to devise a three-dimensional multilayered structure not according to time, as was the case in the present study, but also according to...
the geographic region and country where the observation is made. For example, if students submit observational data in Japan and in the US, both of which are in the Northern hemisphere, the students can compare how the Moon appears in each location on the same day and at the same time. Similarly, if a person wishes to compare the difference in the appearance of the Moon between the Northern and the Southern hemispheres, then it would suffice if students in Japan and Australia, for example, submit observations for their respective locations. The value of using the present system should increase even further if students in the same age group across different geographic locations can exchange views by examining each other’s observational data.

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