Effects of Active Learning in Teaching Practice Using Multi-view Astronomical Teaching Equipment*

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This study examined the learning effects of active manipulation in teaching practice using three types of multi-view astronomical teaching equipment. The results revealed that the level of comprehension of the instructional content was the same for active learning and passive learning, whereas the scores of an application test on the waxing and waning of the moon considering direction and time, which were not taught in class, improved more after active learning. The results of subjective evaluation demonstrated that the students who learned passively were more eager to learn about the waxing and waning of the moon than were students who learned actively. Further, the results suggested that the difference in the groups' understanding had influenced their interest in the teaching equipment.

Key words: Tangible, Interface, Teaching Practice, Active Learning

1. INTRODUCTION

Research on real-world-oriented interfaces (RWIs) has been gaining attention in recent years. These interfaces interact with computers using objects in the real world and specified locations (Rekimoto 2002). The tangible user interface (TUI), proposed by Ishii and Ullmer (1997), is a conceptual human-computer interface that realizes a touch computer, enabling a seamlessly connected 3D interaction between a virtual object and a physical object. These technologies are applicable to many fields (Feiner et al. 1993, Wellner 1993, Aittala 2010, Ishii 2004). Inoue (2010) predicted an increase in environments for real-world interaction in which multiple concepts coexist, such as TUI and augmented reality (AR).

RWIs are also attracting interest in the field of education. For example, Interactive Textbooks (Koike et al. 2001) that integrate paper and electronic media and AR texts that have videos and computer graphic (CG) models superimposed onto the surfaces of paper sheets have been developed (Morita et al. 2011, Setozaki et al. 2011). Mitsuhashi et al. (2010) developed the Paper-Top Interface (PTI), which integrates notebooks and digital education materials, thus reducing the burden of note-taking. In addition, this interface, used in conjunction with a tabletop interface, has other applications such as supporting collaborative learning (Watanabe et al. 2008, Kitahara et al. 2006). For example, Yamaguchi et al. (2007) utilized a collaboration support system (Sugimoto et al. 2004) that enables the integration of personal space and shared space by manipulating physical objects. They demonstrated the practicality of the system through an evaluation experiment on elementary school students. These studies revealed methods to promote effective learning for students through interaction with a virtual environment using physical objects in the real world, without them being conscious of a computer.

However, the loss of interest of young students in science has become a problem. In the field of astronomy, Agata (2004) reported that, approximately 40% elementary school students in the fourth through sixth grades support the Ptolemaic (geocentric) Theory, and the students who did not comprehend the reason for the waxing and waning of the moon comprised more than half of the total number. To understand the mechanism of the moon’s waxing and waning, it is necessary to understand the positional relationship of
revolving celestial bodies with respect to each other and freely switch back and forth between the viewpoints of geocentric and heliocentric theories. However, spatial cognition while shifting viewpoints is a difficult challenge for young students. Matsumori and Seki (1981) conducted a field survey to investigate young students’ spatial cognition. The results showed that students’ understanding regarding the general concept of revolution and symmetrical motion was minimal. In addition, to assist shifts in viewpoints, the presentation of physical objects is more effective than a diagram on paper. According to Masuda’s (2007) field survey on spatial cognition, almost no elementary school student in the fourth and fifth grades coordinated linear measures and shifts in viewpoints.

In astronomy, empirical research on the use of physical objects as educational tools with a focus on the shift in viewpoints of learners has been reported. Arai (2000) reported that employing educational tools with a transparent hemisphere for group learning provided a setting in which students could learn about and practice shifts in viewpoint. Nakakoge et al. (2002) showed that educational materials, such as a globe with a small camera mounted on it, facilitated the merging of perspectives. Moreover, Setozaki and Morita (2006) developed teaching materials that used an actual model mounted with a small camera in conjunction with Web3D. Manipulating physical objects while examining them from the viewpoint of the Earth model promotes students’ understanding of the phenomena that occur owing to the relative positional relationships of celestial bodies, such as the moon’s waxing and waning.

With TUI, in addition to reproducing various phenomena in virtual space, it is possible to provide an intuitive interface using real-world objects. Therefore, it is expected to be a useful educational material for solving issues in astronomy. Yamashita et al. (2007) and Asai et al. (2007) focused on issues in the field of astronomy and developed tangible educational materials. Moreover, Kawasaki et al. (2010) constructed a virtual space for learning about celestial bodies, in which it is possible to shift between the observer’s subjective view and an overhead view in addition to manipulating viewpoints in line with body movements. They suggested that intuitive manipulation facilitates learners’ understanding about the object under study. Morita et al. (2010) developed tangible solar system teaching equipment and showed that it stimulated communication among learners in groups. Using this tangible solar system equipment, Setozaki et al. (2010) conducted individual learning lessons. The subjective evaluation by the participants suggested that active manipulation contributes to improving the comprehension level. Although existing studies suggest that educational materials that employ TUI are helpful, factors that influence learning still need to be examined. Regarding the tangible solar system teaching equipment developed by Morita et al. (2010), detailed analysis of the educational results and improvements to the interface are still required.

This study utilized three types of multi-view astronomical teaching equipment: 1) tangible solar system teaching equipment, developed by Morita et al. (2010), that coordinates model movement with virtual objects; 2) multi-view model teaching equipment; and 3) CG teaching equipment. This study aimed to examine the effects of active learning by manipulating astronomical models.

2. MULTI-VIEW ASTRONOMICAL TEACHING EQUIPMENT

2.1. Overview of multi-view astronomical teaching equipment

This study focuses on issues in the astronomical field and utilizes three types of multi-view astronomical teaching equipment: tangible teaching equipment, model teaching equipment, and CG teaching equipment. The equipment mainly focused on teaching the "moon’s waxing and waning."

The multi-view teaching equipment supports shifts in learners’ viewpoints by simultaneously observing two viewpoints. The learner can observe the positional relationship of celestial bodies from an overhead view and from the Earth.

In addition, the three types of teaching equipment are integrated to display each of their contents on the same monitor (Figure 1). Each type of equipment may be used by switching the on-screen image.

2.2. Tangible teaching equipment

Unlike astronomical simulation teaching equipment, tangible teaching equipment is not designed with the Earth’s and moon’s rotation/revolution in its default setting. In addition, it does not have a fixed positional relationship of the models. Therefore, a learner may explore the astronomical positional relationship of the moon to the Earth during
waxing and waning by freely moving the models.

An authoring software for creating AR, Unifeye SDK (by metaio GmbH), was used to allow real-time rendering of the positional relationship of the models (sun, Earth, and moon) set on the table and display the view from the Earth on the monitor as a CG image. Using Unifeye SDK, a webcam recognizes a black and white image, called a “marker,” and captures the location information of the models. However, the tracking fails if even a part of the marker is hidden. Therefore, a marker was placed on the bottom surface of the models to prevent obstacle interference and allow the webcam under the table to recognize the image, thereby improving the recognition rate.

Figure 2 shows the manipulation board as seen from the bottom surface. The manipulation range on the table is composed of an opaque acrylic board, which conceals devices underneath, rendering the learners unaware of their presence.

The four sides of the table are covered with a black acrylic board, and image recognition sensitivity is enhanced with fluorescent lights installed at two places inside the table.
2.3. **Model teaching equipment**

The Earth model is equipped with a wireless miniature camera (410,000 pixels) that displays an image of actual space from the Earth’s perspective on the monitor. Figure 3 shows the Earth and moon models.

For the Earth model, the image of the Earth is attached to a spherical capsule (12 cm in diameter). In addition, it is equipped with a wireless miniature camera and a video transmitter (1.08 GHz) that sends the image from the Earth model. Further, a receiver receives the image from the Earth model and facilitates output on the monitor.

The moon model (8 cm in diameter) has one hemisphere with the image of the moon attached and the other painted black to depict its shadowed side, that is, where sunlight could not reach. Thus, the waxing and waning of the moon model was displayed on the monitor when the model was observed from the viewpoint of the Earth model. To observe the waxing and waning of the moon model, the learners must consider the positional relationship of the sun and moon models when placing them. Therefore, as shown in Figure 4, the learner or teacher manually positioned the moon model so that its shadow would show at the back of the moon model when facing the sun model.

However, when tangible teaching equipment is used in a classroom, the shadow on the moon model cannot be observed from an overhead view because the model is not painted black. The shadow on the moon model can be observed from an overhead view by using the model teaching equipment. Therefore, the learners can learn about the waxing and waning of the moon by simultaneously observing the view from the Earth model and the shadow on the moon model from an overhead view of actual space on the screen.

2.4. **CG teaching equipment**

Figure 5 shows an overview of the CG teaching equipment, which can display an overhead view of the sun, Earth, and moon and the view from the Earth. The Earth’s rotation and the moon’s revolution can be interactively manipulated according to the orbit of the celestial bodies by using the “manipulation panel” on the screen. In addition, the “sub-window” on the screen displays the view from the Earth, which allows learners to observe the moon’s waxing and waning according to the positional relationship of the sun, Earth, and moon.

![fig4](image-url)

**Fig.4. Manipulation of the moon model on the model teaching equipment**

![fig5](image-url)

**Fig.5. CG teaching equipment overview**

3. **METHOD**

3.1. **Teaching Practice**

On May 1, 2010, a teaching practice using multi-view astronomical teaching equipment was administered as a special extracurricular lesson for 50 students at a private high school. A multi-purpose room located in the students’ school was used for this lesson. The students were divided into groups of 3–5 members; each group was then sent to a separate room where an
approximately 20-min lesson was administered. The content of the lesson was about the mechanism of waxing and waning of the moon.

Prior to using the tangible teaching equipment and the model teaching equipment, the students were shown the movements of the Earth and moon using the CG teaching equipment in order to help them understand the movement of celestial bodies. A shared monitor was used for the CG teaching equipment, tangible teaching equipment, and the model teaching equipment. The teacher also presented 2-min lessons by operating the mouse without using the model on the table.

Next, the teacher gave the students assignment that asked them about the relative positional relationships of celestial bodies on the basis of the shape of the moon as observed from the Earth, such as a full moon or a crescent moon. The students worked on the assignment using the tangible teaching equipment and model teaching equipment. The students were instructed to engage in their assignments one at a time and in order, considering the learning effects of communicating with each other and the extent of movement per person on the table.

3.2. Evaluation Method

To verify the effects of active learning with the multi-view astronomical teaching equipment, the students were divided into two groups and were treated differently on the basis of a “Learning Method” factor. Furthermore, to examine the effects of the order in which the tangible teaching equipment and the model teaching equipment were used, the factor “Presentation Order” was included, and the students were separated into four groups on the basis of two factors; each group was treated differently. The CG teaching equipment had a different interface than the tangible and the model teaching equipment, which observe the celestial bodies from the Earth through the manipulation of celestial models. In this teaching practice, the teacher operated the CG teaching equipment as a way of introducing the lesson.

For the “Learning Method” factor, the students who learned actively by manipulating the model when responding to the assignment presented in class were categorized as the “Active Learning Group.” On the other hand, the students who learned passively through the teacher’s manipulation of the model in response to the students’ questions about the assignment were categorized as the “Passive Learning Group.” For the “Presentation Order” factor, the students who were taught using the tangible teaching equipment before the model teaching equipment were categorized as the “Tangible Priority Group.” On the other hand, the students who were taught using the model teaching equipment before the tangible teaching equipment were categorized as the “Model Priority Group.” Figure 6 shows the procedures for the teaching practice.

The students who received different treatment according to the aforementioned two factors were separated into the following groups and evaluated accordingly: “Active and Tangible Priority Group,” “Active and Model Priority Group,” “Passive and Tangible Priority Group,” and “Passive and Model Priority Group.” Table 1 shows the number of students in each group.

![Diagram](image)

**Fig.6. Procedure for teaching practice**

**Table 1. Distribution of Students: 4 Groups According to 2 Factors**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Learning Group (25)</td>
<td>Active and Tangible Priority Group (13)</td>
<td>Active and Model Priority Group (12)</td>
<td></td>
</tr>
</tbody>
</table>

3.3. Objective Evaluations through Tests

(1) Test Structure and Analysis Method

Pre- and post-tests were conducted before and after the teaching practice to evaluate the changes in the students’ comprehension levels via
spatial cognition through the use of the multi-view astronomical teaching equipment for the mechanism of the moon's waxing and waning. Each test consisted of the same questions, and the students were given 10 min to answer each of them.

One test was an instructional content test that was based on the content taught in the lesson and another was an application test that included exercises not taught in the lesson.

A three-way analysis of variance (ANOVA) was conducted using the following three factors:

- Factor 1: Learning Method through active and passive learning (between-subject comparison)
- Factor 2: Presentation Order using tangible teaching equipment and model teaching equipment (between-subject comparison)
- Factor 3: Changes in Scores between pre-and post-tests (within-subject comparison).

(2) Instructional Content Test
This test was administered to evaluate the students' level of comprehension through the use of multi-view astronomical teaching equipment (9 questions, each worth 1 point and a maximum score of 9 points). In this test, the students answered questions on the apparent shapes of the moon's waxing and waning that resulted from the positional relationship of the sun, Earth, and moon.

(3) Application Test
The application test was administered to measure changes in the students' level of comprehension on the mechanism of the moon's waxing and waning on the basis of the students' spatial cognition. The test comprised the following sections: 1) Waxing and waning of the moon considering direction and time (3 questions, each worth 1 point and a maximum score of 3 points), 2) projective spatial cognition with focus on shifts in viewpoints (4 questions, each worth 1 point and a maximum score of 4 points), 3) waxing and waning of Venus observed from the Earth (3 questions, each worth 1 point and a maximum score of 3 points), and 4) appearance of Venus considering distance and temporal concepts (2 questions, each worth 1 point and a maximum score of 2 points). The exercises in projective spatial cognition with focus on shifts in viewpoints were designed with reference to exercises used in Masuda's (2007) field survey on projective spatial cognition.

Diagrams were presented in each exercise, none of which required basic knowledge of issues such as the rotation, revolution, or orbits of the Earth, moon, or Venus.

3.4. Subjective Evaluations through Questionnaires
As part of the post-surveys, students who participated in the lesson using the multi-view astronomical teaching equipment were asked to complete a questionnaire on the following four areas on a four-point scale: interests/attitudes (4 questions), level of self-understanding (4 questions), motivation (4 questions), and feelings toward the teaching equipment (6 questions).

Four points for answering "strongly agree," 3 points for "somewhat agree," 2 points for "do not entirely agree," and 1 point for "strongly disagree" were allocated from which the average scores were calculated. In addition, ANOVA was conducted using the following two factors:

- Factor 1: Learning Method through active and passive learning (between-subject comparison)
- Factor 2: Presentation order using tangible teaching equipment and model teaching equipment (between-subject comparison).

4. RESULTS

4.1. Results of Objective Evaluations through Tests
(1) Instructional Content Test
The valid responses from the test subjects are as follows: Active and Tangible Priority Group = 11; Active and Model Priority Group = 12; Passive
and Tangible Priority Group = 11; and Passive and Model Priority Group = 12.

Figure 7 shows the results of the test on the instructional content. Analysis showed that there was no significant interaction among the factors. Here, the analysis of the main effect showed significant tendencies in the main effect of the Presentation Order ($F(1,42) = 3.02, .05 < p < .10$) and significant differences in the main effect of “Changes in Scores” ($F(1,42) = 24.40, p < .01$). These results show that the students’ test scores improved through this teaching practice, regardless of the Learning Method or the Presentation Order. The results also show that the test scores for the Tangible Priority Group tended to be higher than those for the Model Priority Group.

(2) Application Test

The valid responses from the test subjects are as follows: Active and Tangible Priority Group = 11; Active and Model Priority Group = 12; Passive and Tangible Priority Group = 11; and Passive and Model Priority Group = 12.

The findings of the “application test” are shown by topic in Figure 8.

In the topic of “waxing and waning of the moon considering concepts of direction and time,” the interaction between the factors “Learning Method” and “Changes in Scores” was found to be significant ($F(1,42) = 4.52, p < .05$). Here, the analysis of the simple main effect of “Learning Method” demonstrated no significant difference in either the pre-test results between the Active Learning Group and the Passive Learning Group ($F(1,42) = 2.77, n.s.$) or the post-test results ($F(1,42) = .66, n.s.$). The findings of an analysis of the simple main effect of “Changes in Scores” showed a significant difference between the pre- and post-test scores for the Active Learning Group ($F(1,42) = 10.15, p < .01$), but no corresponding significant difference for the Passive Learning Group ($F(1,42) = .03, n.s.$). These results clarify that the scores related to waxing and waning of the moon considering the concepts of direction and time” improved through active learning and not passive learning.

In addition, there was a significant tendency in the interaction between the factors “Presentation Order” and “Changes in Scores” ($F(1,42) = 3.15, .05 < p < .10$). Here, the analysis of the simple main effect of “Presentation Order” showed a significant tendencies in the pre-test between the Tangible Priority Group and the Model Priority Group ($F(1,42) = 3.82, .05 < p < .10$), with no significant difference in the post-test ($F(1,42) = .06, n.s.$). An analysis of the simple main effect of “Changes in Scores” showed no significant difference between the pre- and post-test scores for the Tangible Priority Group ($F(1,42) = .18 n.s.$), but showed a corresponding significant difference for the Model Priority Group ($F(1,42) = 8.62, n.s.$). These results clarify that the scores related to “waxing and waning of the moon considering the concepts of distance and time” improved for the Model Priority Group but
not for the Tangible Priority Group. In addition, in comparison with the Model Priority Group, the Tangible Priority Group tended to achieve high scores in the pre-test for subjects.

On the subject of "projective spatial cognition with focus on shifts in viewpoints," the interactions among the various factors were not significant. Here, the analysis of the main effects found a significant difference in the "Learning Method" ($F(1,42) = 4.22, p < .05$). From these findings, it became clear that subject scores did not improve, irrespective of "Learning Method" or "Presentation Order." In addition, it became clear that the scores of the Active Learning Group were higher in comparison with those of the Passive Learning Group.

On the subject of "Waxing and waning of Venus as observed from the Earth," the interactions among the various factors were not significant. Here, the analysis of the main effects found that those of "Learning Method" had significant tendencies ($F(1,42) = 3.39, .05 < p < .10$). From these findings, it became clear that subject scores did not improve, irrespective of "Learning Method" or "Presentation Order." Further, it became clear that the Active Learning Group tended to achieve high scores in subjects in comparison with the Passive Learning Group.

On the subject of "appearance of Venus, considering the concepts of distance and time," the interactions among the various factors were not significant. Here, the analysis of the main effect found no significant difference among that of the "Learning Method," "Presentation Order," or "Changes in Scores." These results clarify that subject scores did not improve, irrespective of "Learning Method" or "Presentation Order."

4.2. Subjective Evaluation Questionnaire Results

The results of the subjective evaluation questionnaire are shown in Table 2. Among the subjects who provided valid responses, 13 belonged to the "Active and Tangible Priority Group," 12 to the "Active and Model Priority Group," 12 to the "Passive and Tangible Priority Group," and 13 to the "Passive and Model Priority Group."

In the four items pertaining to "Interests and Attitudes," interactions between the two factors were not significant. Analysis of the main effects of each question item found significant difference in the "Presentation Order" for the question item "I concentrated on the lesson from beginning to end." These results demonstrated that during the lesson, the Tangible Priority Group had greater concentration than the Model Priority Group.

In the four items pertaining to the "Level of Self-Understanding," interactions between the two factors were not significant. Analysis of the main effect of each question item found no significant difference for any of the items. These results clarified that the same level of self-understanding was achieved, irrespective of the "Learning Method" or "Presentation Order.

In the four items pertaining to "Motivation," interactions between the two factors were not significant. Analysis of the main effects of each question item found significant differences in the "Learning Method" for the question item "I want to learn more about the mechanism of the moon's waxing and waning." These results clarified that the students who learned passively felt greater desire to further study the mechanism of the moon's waxing and waning in comparison to students who learned actively.

In the six items pertaining to "Feelings toward the teaching equipment," interactions between the two factors were not significant. Analysis of the main effects of each question item found a significant difference in "Presentation Order" for the question items "It was interesting to study with the model teaching equipment," "I was able to understand the lesson well using the model teaching equipment," "I was able to concentrate on the lesson using the model teaching equipment," "It was interesting to study with the tangible teaching equipment," and "I was able to understand the lesson well using the tangible teaching equipment." These results demonstrated that compared to the Model Priority Group, the Tangible Priority Group had greater interest, greater level of self-understanding, and greater concentration during the lesson with the tangible and model teaching equipment.

5. DISCUSSION

The results of the evaluation through the test on the instructional content clearly showed that even students who learned passively achieve understanding identical to those who actively learn as long as the subjects are based on the instructional content. This may be because the same information was provided regarding the instructional content, regardless of the learning method. In addition, each group received the same instructional content with the CG teaching equipment at the beginning of the lesson. This
suggests that instruction regarding basic knowledge of the mechanism of the moon's waxing and waning through the use of CG teaching equipment helped students understand the instructional content.

The results of the application test clearly showed that the subject scores for “waxing and waning of the moon considering the concepts of direction and time” improved through active learning. One question was related to the positional relationship of celestial bodies from the overhead view of where the moon culminates at sunset, another was about the shape of the moon from the perspective of the Earth, and one was about the shape of the moon when it is observed one week before full moon. The Active Learning Group could obtain the correct answers to the assignments posed during class by physically manipulating the rotation and revolution of celestial bodies. The learners manipulated the astronomical models while observing the moon (presented on a monitor) as seen from the viewpoint of the Earth. In this activity, if one does not consider the observed position of the Earth and does not manipulate the orbital motion of the moon and the rotation of the Earth accordingly, the moon will not be shown on the monitor, making it impossible to obtain the correct answer. On the other hand, the Passive Learning Group was able to position the astronomical models and obtain the answers to the assignments posed during class by pointing out the positional relationship of the celestial bodies on the operation table to the instructor. If the answers incorrectly indicated the positional relationship of the celestial bodies, the students could rearrange the model by pointing out the positional relationship of celestial bodies to the instructor for the second time. Thus, it can be said that compared with the Passive Learning Group, the

<table>
<thead>
<tr>
<th>Question Items</th>
<th>Active Score</th>
<th>Model Priority</th>
<th>F-Value (Interaction)</th>
<th>F-Value (Learning Method)</th>
<th>F-Value (Presentation Order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I had fun learning about celestial bodies</td>
<td>3.1</td>
<td>3.3</td>
<td>3.4</td>
<td>3.0</td>
<td>2.07</td>
</tr>
<tr>
<td>It was exciting to learn about celestial bodies</td>
<td>2.7</td>
<td>2.8</td>
<td>3.2</td>
<td>2.7</td>
<td>1.48</td>
</tr>
<tr>
<td>I thought a lot about celestial bodies</td>
<td>3.0</td>
<td>2.8</td>
<td>3.3</td>
<td>2.8</td>
<td>2.42</td>
</tr>
<tr>
<td>I was able to concentrate on the lesson from beginning to end</td>
<td>3.4</td>
<td>3.0</td>
<td>3.6</td>
<td>2.8</td>
<td>0.64</td>
</tr>
<tr>
<td>Level of Self-Understanding</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>I was able to fully understand the mechanism of the moon’s waxing and waning</td>
<td>3.6</td>
<td>3.2</td>
<td>3.1</td>
<td>3.1</td>
<td>1.51</td>
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<td>I will be able to explain to others what I learned</td>
<td>2.9</td>
<td>2.4</td>
<td>2.7</td>
<td>2.5</td>
<td>0.36</td>
</tr>
<tr>
<td>My questions regarding celestial bodies were resolved</td>
<td>2.8</td>
<td>2.8</td>
<td>3.0</td>
<td>2.8</td>
<td>0.09</td>
</tr>
<tr>
<td>I am now more confident on the subject of celestial bodies</td>
<td>2.8</td>
<td>2.6</td>
<td>2.9</td>
<td>2.5</td>
<td>0.20</td>
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<td>Motivation</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>I want to learn more about celestial bodies</td>
<td>2.4</td>
<td>2.7</td>
<td>2.5</td>
<td>2.3</td>
<td>0.91</td>
</tr>
<tr>
<td>I want to learn more about the mechanism of the moon’s waxing and waning</td>
<td>2.1</td>
<td>2.2</td>
<td>2.7</td>
<td>2.5</td>
<td>0.50</td>
</tr>
<tr>
<td>I also want to learn more about the other planets, Like Venus</td>
<td>2.4</td>
<td>2.4</td>
<td>2.8</td>
<td>2.4</td>
<td>1.73</td>
</tr>
<tr>
<td>I would like to take a class like this again</td>
<td>3.0</td>
<td>2.9</td>
<td>3.2</td>
<td>2.7</td>
<td>0.86</td>
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<tr>
<td>Feelings toward the Teaching Equipment</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It was interesting to study with the model teaching equipment</td>
<td>3.5</td>
<td>3.0</td>
<td>3.7</td>
<td>3.4</td>
<td>0.72</td>
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<td>I was able to understand the lesson well using the model teaching equipment</td>
<td>3.5</td>
<td>3.0</td>
<td>3.5</td>
<td>3.2</td>
<td>0.38</td>
</tr>
<tr>
<td>I was able to concentrate on the lesson using the model teaching equipment</td>
<td>3.5</td>
<td>3.2</td>
<td>3.2</td>
<td>3.6</td>
<td>0.04</td>
</tr>
<tr>
<td>It was interesting to study with the tangible teaching equipment</td>
<td>3.5</td>
<td>3.2</td>
<td>3.2</td>
<td>3.6</td>
<td>0.00</td>
</tr>
<tr>
<td>I was able to understand the lesson well using the tangible teaching equipment</td>
<td>3.6</td>
<td>3.3</td>
<td>3.4</td>
<td>3.1</td>
<td>0.00</td>
</tr>
<tr>
<td>I was able to concentrate on the lesson using the tangible teaching equipment</td>
<td>3.3</td>
<td>3.0</td>
<td>3.5</td>
<td>3.1</td>
<td>0.09</td>
</tr>
</tbody>
</table>

** : p < .01, * : p < .05, † : .05 < p < .10, n.s. : No significant difference
Active Learning Group learned by continuously manipulating the model in accordance with the time axis that related to rotation and revolution. This suggests that the process of exploratory learning through manipulation of rotation and revolution by oneself promoted the learners’ developmental thinking on subjects that consider the concepts of direction and time.

The subject scores for “waxing and waning of the moon considering the concepts of direction and time” also improved for the Model Priority Group. In this subject, the pre-test scores for the Model Priority Group showed a significant tendency to be lower than those for the Tangible Priority Group. Setozaki et al. (2009) administered teaching practice using multi-view virtual reality teaching equipment for the mechanism of the moon’s waxing and waning and performed an evaluation from the standpoint of the proficiency level. The findings demonstrated that the scores improved among students who tested low in the pre-test on application assignments, which are developmental subject exercises (low-score group). However, the scores did not improve among the students who tested high in the pre-test (high-score group). Therefore, in the subjects of this teaching practice as well, the marginal significance of pre-test scores was surmised to be one factor in the improvement of scores in the Model Priority Group.

On the other hand, in the subjects of “projective spatial cognition with focus on shifts in viewpoints,” “waxing and waning of Venus as observed from the Earth,” and “appearance of Venus considering the concepts of distance and time,” the scores did not improve irrespective of the “Learning Method” or “Presentation Order.” Accordingly, these results demonstrate that an understanding of “the mechanism of the moon’s waxing and waning” did not transfer to these subjects. It is surmised that in addition to the composition of the teaching equipment and the lesson design in this study, the short lesson time of 20 min was a mitigating factor against knowledge transfer.

The results of the subjective evaluation revealed that the students who learned passively experienced more desire to further study the mechanism of the moon’s waxing and waning than students who learned actively. Because the Passive Learning Group did not actually handle the models, the desire to handle tangible and model teaching equipment may have been a factor that heightened learning motivation.

It was demonstrated that students’ levels of concentration during the lesson and their feelings toward the teaching equipment differed depending on the presentation order of the model and tangible teaching equipment. The test on the instructional content found that Tangible Priority Groups tended to achieve higher instructional content test scores than Model Priority Groups. Therefore, it is surmised that the difference in the level of understanding of the instructional content between the two groups had an effect on the learners’ interest in the teaching equipment and level of self-understanding.

6. CONCLUSION

This study administered teaching practice using three types of multi-view astronomical teaching equipment and examined the effectiveness of learning by active manipulation.

The results of the test on the instructional content clearly showed that the level of learners’ understanding of the lesson content improved for both the Active Learning Group and the Passive Learning Group. In addition, the results of the application test clarified that the active manipulation of the tangible and model teaching equipment furthered learners’ understanding of the content during the lesson and improved the scores related to “waxing and waning of the moon considering the concepts of direction and time.”

The results of the subjective evaluation clarified that the students who learned passively experienced a greater desire to further study the mechanism of the moon’s waxing and waning than students who learned actively. Moreover, it was surmised that the difference in the level of understanding of the instructional content between the two groups had an effect on learners’ interest in the teaching equipment and level of self-understanding.

A subject for future research will be to ascertain the utility of teaching equipment that focuses on learner characteristics. Moreover, the present study did not consider the utility of the multi-view feature of the teaching equipment. Therefore, using methods such as experimental design, interviews, and observation, we will investigate the equipment’s utility in terms of image presentation from the Earth’s perspective.

7. SUMMARY

This study examined the learning effects of
active manipulation in teaching practice using three types of multi-view astronomical teaching equipment. The results revealed that the comprehension test’s average score improved equally after both active learning and passive learning, whereas the scores of an application test’s average on the phases of the Moon considering direction and time improved more after active learning. The results of subjective assessment performed after learning demonstrated that students who learned passively were more eager to learn about the phases of the Moon than were students who learned actively. Further, the results suggested that the difference in the groups’ understanding was related to their interest in the teaching equipment.

KEYWORDS: Tangible, Interface, Teaching Practice, Active Learning.

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