Utilization of Hands-On and Simulation Activities for Teaching Middle School Lunar Concepts

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Abstract. A great deal of literature exists surrounding the misconceptions that students have regarding the moon, specifically how the moon phases and eclipses occur. These studies provide teachers with information regarding what misconceptions their students may come to the classroom with as well as some ideas as to how to approach and correct them. However, these methods are not always validated with classroom-based research, and much of the research that has been done is in the high school and college setting. As such, we have undertaken a study to investigate what a group of middle school students know about the moon pre-instruction, and how hands-on activities and computer simulations affect student learning and understanding of these topics. The results of this project show that neither supplementation was distinguishably more effective in improving student test scores, as measured by Hake gains; this may be an artifact of high pre-test scores, as described herein.

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INTRODUCTION

The Pennsylvania State School Standards in Science include concepts of the moon and its phases in grades 3-8 [1]. In particular, by the eighth grade students are expected to know and understand why the moon goes through phases as well as be aware of what an eclipse is and the different types of eclipses and how they occur.

The research question guiding this study is: *Do students benefit when traditional notes are supplemented with interactive computer simulations or a hands-on activity? Do such strategies affect those students with Individualized Education Plans(IEPs) differentially?*

LITERATURE REVIEW

Research indicates that students come into the classroom with numerous misconceptions concerning the moon and how the moon phases occur [2, 3]. The biggest obstacle that has to be overcome by teachers is the correction of these misconceptions. For example, when a student is questioned about the moon it is common for them to have a belief that the moon phases are due to shadows from the earth [3, 4]. Another issue that is faced is that students sometimes believe that the moon is not visible during the day; even though all of them have probably seen the moon during the day, this preconception causes them to believe that the sun and the moon are found on opposite sides of the earth [5, 6].

To address these alternative conceptions, researchers have suggested a variety of teaching techniques [2, 7]. One of the suggested strategies includes placing a light in the center of the classroom and having students represent the earth and moon [8]. Barton split the class into small groups and had each create models of seven Earth-based astronomical phenomena, including moonrise and moonset, moon phases and eclipses [9]. Lastly, in order to try and correct the misconceptions that the moon can only be found in the sky at night, a demo can be done that requires students to draw the phases of the moon on a plate, include the times of day at which each of these phases can be seen and place half a plate overtop that represents the horizon, thereby demonstrating to students that the moon indeed can be seen during the day [10].

In order to identify the misconceptions that the students are bringing into the classroom, the Lunar Phases Concept Inventory (LPCI) was created by Lindell *et al.* [11, 12]. The LPCI is a research-validated instrument that is widely used within the astronomy education research community and will be one form of data collection used to answer our research question, and it will be supplemented by student discussion via voice recording and written responses [14].

METHODS

This research project is a mixed-methodological study that utilized both quantitative and qualitative research methods. Specifically, this study consisted of both grounded theory and phenomenographical approaches. A phenomenographic approach is one that seeks to describe how individuals understand a phenomenon[16]. This approach provided the opportunity to examine how the participants approached the task at hand from their own perspective instead of from any preconceived notions. Next, a grounded theory approach was utilized as a means of eliciting themes across all students. The alignment of the grounded theory approach with the scientific method ensures significance of results and compatibility between theory and observations[17, 18]. Another primary feature of grounded theory is that the data itself guides the results of the study without any bias from the researcher; this allows for the development of a truly student-centered theory[19].

Guided by the above methodologies, data collection for this study began with a pre-test based upon a modified version of the Lunar Phases Concept Inventory (LPCI) for college undergraduates [11, 12]. The majority of the questions were modified by simply reducing the number of distracters so that each question had only four options to choose from. However, 8 of the original 20 content questions were removed entirely because the material was not part of the middle school curriculum. In accordance with federal law, the test had to be further modified for those students identified as being in need of learning support (students who had an IEP). These students received a version with even fewer distracters, a modification that helped to alleviate the amount of distress that those students would have experienced. The same modified LPCI was given as a matched-sample post-test following instruction. All of the data in combination was then used as a comparison tool as to the effectiveness of the supplementations.

There were approximately 130 student participants, all enrolled in one of six seventh grade earth and space science classes. Each class section was taught the same material and all were given an identical introduction to lunar phases. Afterward, three of the classes had the information supplemented by hands-on activities while the three other classes had the information supplemented by computer simulations. All of the classes had to complete a 'Phases of the Moon Diagram' through the supplementation procedure.

Those students who were completing the hands-on activity were given a Styrofoam ball that represented the moon. The Earth was represented by the student's head and a light was placed in the center of the classroom to represent the sun. The students were asked to make the moon go through its orbit and discover the phases while completing the task. The computer simulation used for this study is a free program that can be found online[20]. The simulation groups had three scenarios that they were looking at: the first scenario made them identify which side of the moon was lit up by the sun, the second made them correctly identify the phases of the moon within the moons orbit, and the third related the phases to time to complete a rotation. Both activities allowed the students the opportunity to visualize the process by which moon phases occur.

After all of the information was covered with each class and the different supplementation methods had been introduced, all students took an identical post-test that included the same information as the pre-test. Accounting for student absences, there were 116 matched pairs for the pre-test and post-test. The post-test was given three days after the pre-test and there seemed to be no positive or negative effect from the students having already seen the test. An extended post-test was given one week after the pre-test, at this point the astronomy unit had been completed, students had now covered the topics of eclipses, stars and the universe, 135 students completed the extended post-test.

The data presented in the following section are a result of the pre- and post-test analysis as well as a qualitative analysis of the discussions with students that occurred before, during, and after the different implementations. This analysis primarily uses Hake gains as a means of comparing the interventions[21].

RESULTS AND DISCUSSION

Comparing pre- and post-tests results using the modified LPCI yielded an unexpected set of data. It is clear that as students progressed through the supplementary activities, their understanding of the materials and concepts was strengthened. Anecdotally, this was illustrated by the fact that students were observed to be holding up an 'imaginary moon' while taking the post-test. However, the numeric data present a rather fuzzy picture of the student interactions with each supplement; these results are discussed in more detail in the remainder of this section.

Pre-Test Scores

Research suggests that students have extreme difficulty understanding moon phases and why they occur [3-6, 8, 14, 22]. This did not seem to be the case with this group of students, as evidenced by the fact that the average pre-test score was 5.5 out of 12 or around 46%, with a few students obtaining a perfect score. While the version of the LPCI used here was modified for use with much younger students, it is still significant to note that on the original LPCI pre-test scores were in the neighborhood of 32-42% correct. While there is no way to explain the difference based on the existing set of data, it is still important to consider the effects of the high pre-test scores on the gains achieved by each intervention.

Pre-/Post-test Gains

As shown by the data found in Table 1, students who completed the hands-on activity typically had higher gains than those who used the computer simulation. Overall, however, there is no statistically significant difference between the students who used the computer simulation vs. those students who completed a hands-on activity. Further, the gains for hands-on and simulations were 0.26 and 0.23, respectively, which puts them below the 0.3 threshold for mid-range gains[21]. An overall average score for all students completing the post-test was approximately 62% thereby demonstrating improvement after instruction.

TABLE 1. Comparison of Hake gains for students between simulation and hands-on supplementation.

	Simulation	**Hands-on**
All Students	0.23	0.26
IEPs	-0.33	0.12
No IEPs	0.28	0.29

The data from the pre- and post-test were also analyzed to determine whether either intervention helped those students within the Individualized Education Program (IEPs) more than the others. As shown, the simulation and hands-on activity had nearly equal Hake gains for those students who do not have an IEP. However, it was discovered that the use of computer simulations as a supplementary tool was detrimental to the students with IEPs as determined by the calculated Hake gain of -0.33, whereas these students showed improvement with the hands-on approach with a gain of 0.12. Although the gain by the IEP students completing the hands-on activity did not fall within the level for mid-range gains, there was improvement, supporting the inference that hands-on activities are more beneficial to students[23].Even during the pre-test, there were many students creating their own visualizations with their hands, modeling the movement of the moon through the sky, as well as closing their eyes and, presumably, picturing the moon as they see it every night. Similar actions were observed from the students during the post-test. The difference was that those students who completed the hands-on activity were pretending that they had a moon in their hand and orienting themselves within their seats so that they were facing the "sun." These same actions were not evident in the classes who completed the computer simulations and, in fact, they exhibited less behavior than on the pre-test. Perhaps the ability to have a physical and kinesthetic connection to the material was even more beneficial for students with IEPs, which would help account for the differential benefit of using the hands-on activity for that subset of the population. According to Sadi and Cakiroglu, hands-on enriched instruction is more beneficial to students when compared to traditional classroom instruction, this is supported by the data in Table 1, not only by the IEP students but by all of the students involved in the project gaining 0.26[23].

Question-by-Question Analysis

Because of the challenge of considering the IEP and non-IEP students together, they are separated for the by-question analysis of the modified LPCI. Using that measure, the non-IEP students reached that level on questions 1, 3, 6, and 9. These questions reflect the essence of the project because students had to understand topics such as how long a rotation of the moon takes, why moon phases occur and what moon phase would be found at specific locations within its orbit. The fact that these questions showed a gain in student understanding highlights the point that these strategies are effective within the classroom.

TABLE 2. Hake gains for all students, only students without IEPs and only students with IEPs on individual questions.

	All Students	**Non IEP Students**	**IEP Students**
1	0.34	0.38	0.13
2	0.18	0.23	-0.15
3	0.38	0.43	0.11
4	0.13	0.10	0.26
5	0.17	0.17	0.20
6	0.28	0.33	0.01
7	0.07	0.08	-0.03
8	0.00	0.00	0.01
9	0.31	0.34	0.11
10	-0.13	0.08	0.10
11	0.10	0.15	0.27
12	0.23	0.23	0.24

Extended Post-test Analysis

After a period of one week the students were presented with a selection of the LPCI questions to see how much of the information had been retained. W The average percentage of correct answers for students that took the test was approximately 71%.

TABLE 3. Hake gains for all students a period of one week after instruction was completed.

	All Students	**Non IEP Students**	**IEP Students**
1	0.25	0.30	-0.06
3	0.35	0.39	0.22
6	0.10	0.12	0.17
7	0.27	0.34	0.11
10	0.39	0.51	0.11

When calculating the Hake gains the non-IEP students showed significant improvement on one question in particular as shown in Table 3 having a Hake gain of 0.51. This question was directly related to the moon phase diagram, students were required to predict what the moon would look like from Earth in a certain position.

After comparing all students results the post-test and extended post-test values for those questions that were selected only marginally changed. With the exception of question 1 the Hake gains for students with IEPs improved. An explanation for this would be the additional time for the students to absorb and comprehend the information as well as additional review and supplementation with other topics.

CONCLUSIONS AND FUTURE WORK

This project provides insight into the dynamic construction of knowledge and the ability of students to modify their previous misconceptions through hands-on and computer simulation activities. Overall, the results show a slight advantage to using a hands-on activity over a computer simulation for the general population. The Hake gains between the computer simulation and hands-on group were not statistically significant enough to say that one supplementary procedure was better than the other. However, the data are clear that students with IEPs gained a more complete understanding of the topic through hands-on activities, and may have been disadvantaged by using the computer simulation instead.

The low gains that were obtained in this project might be partially explained by the research population. It is common for middle school students to second guess themselves which would help to explain why some students were capable of receiving a lower score on the post-test. Additionally, with this level of student there is an idea that ungraded assignments do not need to be completed to the best of their ability. The pre- and post-tests did not affect student grades therefore some students may not have taken them seriously and made mistakes that would not have occurred otherwise.

Future work in this project could include a combination of the two supplementations. A knowledge baseline would be formed from student scores on the pre-test and compared to student achievement scores on the post-test. The topic would be introduced within the traditional classroom setting and reinforced with a combination of interactive hands-on and computer simulation activities. integrate

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