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The Use of Interactive Lecture Demonstration with Interactive Simulation in Enhancing Students' Conceptual Understanding in Physics

Ma. Kristine L. Estipular, Lydia S. Roleda*
De La Salle University
**Corresponding Author: lydia.roleda@dlsu.edu.ph*

Abstract: The effectiveness of experiential learning in science particularly in basic education is widely accepted. In the Philippines, however, it is not uncommon that science is still being taught by traditional lecture, that is, all lecture. There is a scarcity of laboratory materials especially in government schools. One way to address this is by interactive simulation in teaching high school science. This is an action research aimed at improving teaching Grade 9 science using interactive simulation. The first round was carried out based on the PDSA cycle. The research environment was a public high school in a major city in the Philippines. The participants were 2 intact classes who were given instruction in basic physics for 4 weeks. Eight interactive simulations covering topics on motion, forces and mechanical energy were used. Pre- and post-tests scores of the students showed that there is a significant improvement on the students' conceptual understanding of these topics. In addition, lived experiences of the teacher were also presented as each stage of the cycle is undertaken.

Key Words: guided inquiry; interactive simulations; ILDs

1. INTRODUCTION

The Enhanced K-12 Basic Education Program has been implemented in the Philippines since SY 2012-2013. The goal of the said program is to have an education system that will give basic learning needs of students specifically, quality education with excellence and enhanced skills and competencies that will allow them to be productive or pursue higher education. Because of the enhanced curriculum, teachers provide learning strategies that give the students learning experiences to make them globally competitive with high academic standards. In making the curriculum relevant to the learners, illustrations and activities were emphasized to make the lesson easier to understand. This, in effect, will help the students obtain in-depth knowledge, skills, values and attitudes towards learning. This, however, requires various educational innovations and facilities.

Teaching science requires a great deal of visualizations and experiments. That is why every school should have science laboratories where students can experiment and explore. This can also spark their interest in the lessons. Science experiments will allow students to discover new ideas that will scaffold their learning. However, not all schools in the Philippines have enough laboratory equipment, especially in public schools. Although the Philippine government is building more schools, most of these schools lack or do not even have the basic science laboratory facilities and equipment commonly used in teaching basic science. Or, in some developing schools, the laboratory equipment is not adequate for large number of students. One example is the 5-year old secondary school in a major city in the Philippines. It is a small school but caters almost

5,000 secondary students with an average of 55 students per class. It has only one science laboratory with limited laboratory apparatus. It is a challenge for the science teachers to provide the students enough experience to understand more the science lessons because of this situation.

Hence, developing an active learning environment to promote students' understanding has been a prime concern. Teaching supplements such as showing videos of experiments, using improvised materials and using computer simulations are some of the alternatives that can make learning science more educational and engaging. Physics Education Technology (PhET) simulations are one of the most common computer simulations founded by Wieman at the University of Colorado. It can be a virtual laboratory, can visualize the invisible, can help students learn concepts, and can provide an active learning environment.

Interactive lecture demonstrations also promote an active learning environment. It is a three-step activity based on a classroom demonstration that can be an experiment, survey, or a simulation where the students will predict the outcome, observe the demonstration and explain what occurred in the activity. This type of teaching strategy promotes better conceptual learning than the traditional lectures alone Mazollini, et al., (2011). Aiming for a better education demands exploring new and different teaching strategies. The way students are presented with a lesson greatly determines learning. Students tend to be more interested in lessons if they will be more engaged in the presentation of the lesson (Crouch, et al., 2005). Students who understand the underlying concepts prior to demonstration are more likely to observe and remember it correctly (Miller et al., 2013). Moreover, students will be more engaged in the subject if they are free to formulate their own hypotheses and predict their own outcomes. It is vital that students are encouraged to make their own predictions and correct observations. This will promote not only conceptual understanding, but also higher order thinking. From this, they will be encouraged to exercise their own critical decision making. Students' engagement and students' knowledge heavily rooted by basic concepts is very useful in the overall effectiveness of an interactive classroom demonstration.

Guided inquiry is a mode of teaching designed to develop students' level of thinking and process skills. It allows the students to gain deeper understanding through various resources in their dynamic environment. It creates a learning environment that allow the students to learn by giving them opportunities to construct their own meaning from their prior knowledge. Through this approach, students experience a high level of motivation and engagement that will help them develop deeper understanding on the lessons.

Guided inquiry is also a mode of learning. It is very beneficial for the students to learn the lessons in a more motivating way. Through guided inquiry, students gain a sense of their own learning process by successfully making a project from start to finish. They learn skills which enables them to use in making projects and applying it to real-life situations.

Interactive simulation is an effective learning tool that gives a game-like environment on students. Wieman, et al. (2008) explained that simulation can be used in interactive lecture demonstrations. The most effective way to use simulation in a lecture is by showing a scenario and the students will give their own predictions. They will discuss their prediction with their classmates to come up with their final prediction. The teacher will run the simulation after hearing students' predictions and the students will observe what was illustrated by the simulation. They will write down their observations and there will be a whole class discussion.

Implementation of interactive lecture demonstration in the Philippines had been successful using different materials. Using laboratory experiments in the interactive lecture demonstrations have shown positive effect on students' conceptual understanding. However, this teaching strategy is very limited to schools with complete and modern laboratory apparatus. Interactive simulations can be used to replace experiments with real equipment. Hence, the purpose of this study is to investigate how computer simulations in guided inquiry enhance students' conceptual understanding in physics.

2. METHODOLOGY

2.1 Participants

The participants were two Grade 9 classes of a developing secondary school in a major city in the Philippines. The two intact classes with average grades ranging from 88%-95% were the participants. There were 86 respondents, 24 boys and 62 girls, ages 15-16 years old. The school offers regular junior high school curriculum. The school has 26 Grade 9 classes with an average class size of 52 students. The respondents were aware that their class was used in this study.

2.2 Instruments

New interactive lecture demonstration lessons were constructed based on the interactive lecture demonstrations of Sokoloff and Thornton (1997). It was designed from physics lessons in Grade 9 of the K-12 curriculum, specifically, forces, motion and mechanical energy. Interactive simulations from PhET, Physics Classroom and Physics Front were used instead of real-time experiments.

A standard concept test distributed by the Division of City Schools was administered to the students. The concept test is an assessment of students' conceptual understanding of Grade 9 Physics lessons. The concept test consisted of 33 items.

Students used journals together with their activity sheets. They reflected on how comfortable they were (or not) with the guided inquiry learning, how they enjoyed learning the lessons and how the guided inquiry learning helped them understood physics concept.

2.3 Procedure

The intervention was performed during the fourth quarter of a school year. The modules used covered topics on forces, motion and mechanical energy. The guided inquiry teaching approach was conducted for four (4) weeks, 3 sessions each week. Each class session lasted for 50 minutes.

Data gathering started by administering the concept test as the pre-test to identify students' prior knowledge and understanding on forces, motion and mechanical energy. The guided inquiry was conducted after administering the pre-test. In every start of the learning session, prediction sheets are given to the students. It consists of questions answered through their prior knowledge about the lesson. The students were given time to discuss their prediction with their classmates.

Eight interactive simulations were used in the study. The guided inquiry learning for motion have 5 interactive simulations. It took 8 days to complete the two topics covered. Two interactive simulations were used for the module on forces that took 4 days to complete. On the module of mechanical energy, one interactive simulation was used in a four-day guided inquiry learning. During the guided inquiry stage, the students were prompted through the step by step process that they needed to do in the interactive simulations activities. The students were given enough time to explore the simulations. Since the topics involved computations, a day for each topic were given for the problem solving.

After the instruction, the activity sheets were given to the students. The questions in the activity sheets were similar to the prediction sheets. The students were given time and were allowed to correct their misconceptions on the lesson and answer the activity sheets based on the things they learned and discovered during their exploration of the interactive simulations.

The lessons were discussed by the teacher using the responses of the students in their activity sheets. The students then compared their answer in the prediction sheet and activity sheet. This process enabled them to asses their (mis)conceptions and learn the correct ideas. After the learning session, the students were asked to answer some questions in their journal for their views about the process of guided inquiry with interactive simulations.

After conducting all the guided inquiry with interactive simulation activities for the module, the students were given a post-test that was the same test given prior to instruction. The normalized gains were used to determine the effectiveness of the instruction.

The improvement in the students' conceptual understanding was determined using the Hake normalized gain, g (Hake, 1998):

$$< g >= \frac{(\% < post > - \% < pre >)}{100 - \% < pre >} ,$$

where brackets indicate group average. For this purpose, the 2 classes were considered one group. The normalized gains were categorized by Hake as: high for <g> > 0.7; moderate for 0.3 < <g> < 0.7; and low for <g> < 0.3.

3. RESULTS AND DISCUSSION

3.1 Students' Conceptual Learning

The raw scores of the students in the concept test were expressed in percent form and converted into its grade equivalents using the standard-based grading system of the K to 12 Basic Education Program.

Figure 1 shows that 95% of the respondents attained a passing score (60% of the highest possible score was the standard for achievement). This is a strong indication that the guided inquiry learning with interactive simulation is an effective approach in teaching forces, motion and mechanical energy.

TABLE I. TEST OF DIFFERENCES OF THE CONCEPTUAL PRETEST AND POSTTEST

Concept Test	n	Mean		<g>	SD
		*Pre-Test**	*Post-Test**		
Motion	10	3.74	7.99	0.65	0.28
Forces	13	5.08	9.21	0.5	0.22
Mechanical Energy	10	4.38	8.20	0.66	0.27

3.2 Impact of Guided Inquiry with Interactive Simulations

A paired sample t-test was used to determine whether the difference in the mean score of the pretest and posttest is significant. Table 1 shows that the computed t value of 24.71 is greater than the t critical value of 1.66 at a level of significance of 0.05. This result indicates that the mean of the posttest scores is significantly greater than the mean of the pretest scores. The gain in the performance of the students in the pretest and posttest was identified through the Hake (1998) formula.

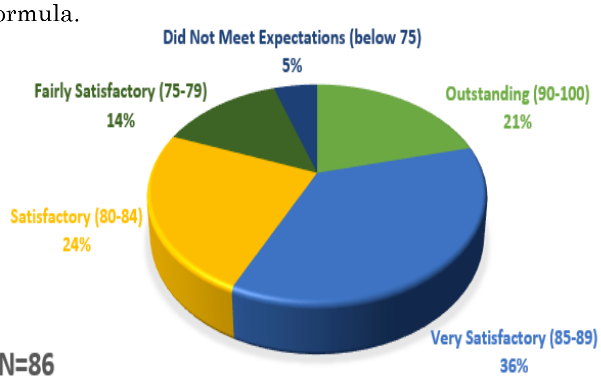

Fig. 1. Score distribution in the concept test

Table 2 shows that the gain in students' conceptual understanding is 0.61 which is classified as moderate. Therefore, the use of guided inquiry with interactive lecture demonstration has moderately improved students' conceptual understanding in learning forces, motion and mechanical energy. Table 3 explicitly shows the statistical differences of the conceptual pretest and posttest of the students. The posttest was administered to know the conceptual understanding of the students after the use of guided inquiry with interactive simulations. The mean score of 25.27 (77%) of the posttest exceeded the passing score of 20.00 (60%) set by DepEd Order no.8 s.2015. This indicates that the students have an above required conceptual understanding on motion, forces and mechanical energy. The decrease in standard deviation from 3.43 to 3.15 indicates that the effect of ILD on each of the students' performance is about the same.

3.3 Students' Conceptual Understanding

Ten items on the concept test focus mainly on Motion specifically, uniformly accelerated motion, freefall and projectile motion. Table 4 shows the mean of the scores of pretest, posttest and normalized gain of the students in the concept test on motion. The mean of the normalized Hake gain is 0.65 which indicates an almost high gain on students' conceptual understanding. A value of 0.28 SD indicates that the normalized gain of the students tends to be close to the mean and signifies that most of the students obtain a Hake gain between ~0.4 and ~0.9, suggesting moderate to high gains.

TABLE II. TEST OF DIFFERENCES OF THE CONCEPTUAL PRETEST AND POSTTEST

t-Test: Paired Two Sample for Means	Pretest[a]	Posttest[a]
Mean	13.34	25.27
t Stat	-24.71	
t Critical	1.66	

[a] Maximum possible score=33

TABLE III. NORMALIZED GAIN FOR PHYSICS CONCEPT TEST

	N	Pretest Mean	Posttest Mean	<g>
Physics Concept Test	86	13.34	25.27	0.61

TABLE IV. TEST OF DIFFERENCES OF THE CONCEPTUAL PRETEST

AND POSTTEST

	Pretest	Posttest
Mean	13.34	25.27
Standard Deviation	3.43	3.15
Minimum	7	14
Maximum	22	30

Thirteen items focus on forces, specifically impulse and momentum, collision and conservation of momentum. The mean score on the test increased from 5.08 to 9.21 after the intervention. The mode of the pretest is 6 which is less than half of the 13 items of forces on the concept test. However, after the intervention, most of the students got 77% of the test correctly which is greater than the passing score of 65%. The normalized Hake gain of the test is classified having a moderate gain which depicts a positive outcome on the use of the intervention. The result of the test and the normalized gain indicates that the demonstration have contributed on the increase of students' conceptual understanding on forces.

Ten items probed students' conceptual understanding on Mechanical Energy, specifically Kinetic Energy, Potential Energy, and Conservation of Mechanical Energy. The mean score of the posttest have increased two times of the mean score of the pretest. Out of 10 items, most of the students were able to answer 8 of the concept test correctly. The normalized Hake gain in the concept test is classified in the "high" moderate which directs a positive point on the use of guided inquiry learning with interactive simulation to enhance students' conceptual understanding on mechanical energy.

The test items in the concept test with very high normalized gain is shown on Table 5. Item numbers 1 and 23 have the highest percentage of correct answers by the students. Both items were on application of momentum on problem solving. Interestingly, these items were not directly influenced by the use of simulation in the guided inquiry learning. This suggests transfer knowledge. The students were able to apply what they have learned to other situations.

TABLE V. TEST ITEMS WITH HIGH NORMALIZED GAIN IN THE CONCEPT TEST

Item No.	**Subject**	**% of Students with Correct Response**		<g>
		Pretest	*Posttest*	
1	Forces	81	99	0.95
23	Forces	84	99	0.94
30	Mechanical Energy	48	97	0.94
16	Forces	41	92	0.86
24	Forces	64	93	0.81
6	Mechanical Energy	38	87	0.79
29	Mechanical Energy	36	86	0.78
17	Motion	41	85	0.75

Item number 16 shown on Fig. 2 is a test on the application of conservation of momentum. Fifty-one students obtained incorrect answers during the pretest. Twenty-eight percent (28%) of the students thought that as block 1 swings down, block two will swing to the right and block 1 will swing back to its position and 24% believed that both blocks will swing together. During the guided inquiry learning, students tried this case in the PhET 'Collision Lab'. In this interactive simulation, students can change the mass, position, velocity and elasticity of two disc and observe how momentum varies as they collide. Students have observed that when an object moving with a given velocity collides to an object at rest, the momentum will be conserved where the object at rest will move and the object moving will stop. With this observation, 92% of the students were able to answer the item number 16 correctly (A). Their misconception on the collision of a moving object and an object at rest have been corrected after the intervention. This attests to an increase in the conceptual understanding of students on momentum.

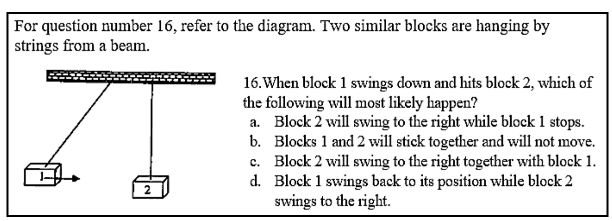

Fig. 2. Item Number 16 in the Concept Test

The analysis of students' responses in the pretest, posttest activity sheets, and prediction sheets, revealed that the use of guided inquiry learning with interactive simulation have a great impact on students conceptual understanding on motion, forces and mechanical energy. Students are challenged to compare predictions based on their beliefs to their observation in the interactive simulations.

3.4 Students' Views

The perceptions of the students were gathered from their journal in every guided inquiry lesson. Most of the students feel comfortable on using computers and learning new software. According to the students, they liked most the use of the interactive simulation during the guided inquiry. Students' skills improved with the use of workstation computers and they learned teamwork. Students were able discuss their results with their classmates. The simulations offered a less intimidating approach to teaching phyisics topics to students. With these, the interactive classrooms promote holistic skills, including thinking, inquiry, creativity and reflection by students, often involving peer review and critiquing. Students were more engaged in the activities and at the same time developed interpersonal skills while working on those activities with their peers.

4. CONCLUSIONS

Guided inquiry with interactive simulations were used in teaching high school physics to Grade 9 students. Eight interactive simulations were used, 5 for motion, 2 for forces and 1 for mechanical energy. Parallel pre-test and posttest were used to determine the effectiveness of the teaching strategy. Results showed that $\langle g \rangle = 0.61$, indicating that there was an almost high Hake gain among the students. This points to a significant improvement in the conceptual understanding of the students in forces, motion and mechanical energy before and after the use of guided inquiry learning with interactive simulation.

The journals of the students revealed that the use of simulations in the guided inquiry learning have made them more interested in learning physics. Although the prediction stage of the interactive lecture demonstration had been difficult for some of the students there were many who shared they enjoyed it, particularly when they defended their predictions to their classmates. According to them, the fun in doing the activities in the guided inquiry motivated them to learn more.

5. ACKNOWLEDGMENTS

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