Effects of Computer Simulations and Constructivist Approach on Students’ Epistemological Beliefs, Motivation and Conceptual Understanding in Physics

Vergel P. Mirana

Abstract — The study investigated the effects of developed lessons integrating computer simulations and constructivist approach on students' Epistemological Beliefs, Motivation and Conceptual Understanding in Electricity. It sought to answer the following questions: What are the effects of developed lessons on Epistemological Beliefs, Motivation and Conceptual Understanding? Is there any statistical significant difference on students' pretest and posttest on Epistemological Beliefs, Motivation and Conceptual Understanding?

The investigation used the pre-experimental single-group pretest and posttest study. Research Instruments include: Epistemological Beliefs in Physical Sciences, Science Motivation Questionnaire and Conceptual Test in Electricity which were used in the pretest and the post test. The study was conducted among seventy-two (72) Fourth Year High School students of Central Bicol State University of Agriculture- College of Education-Laboratory High School. They were taught using PhET and other web-based simulations, constructivist approach, formative assessment classroom technique from October 13 to November 21, 2014.

The results revealed that the over-all Epistemological Beliefs of the students did not change significantly; only along Nature of Knowing and Learning and Real-Life Applicability, with p-values of 0.001 and 0.040, respectively. Students' Motivation had over-all significant improvement especially along Intrinsic Motivation, Self-Efficacy and Self-Determination with corresponding p-values of 0.016, 0.024, and 0.036. Furthermore, the conceptual understanding of the students significantly improved with a p-value of 0.001.

Generally, it can be concluded that the use of computer simulations and constructivist approach did not alter students' epistemological beliefs entirely however, it can be engaging and effective in promoting students’ understanding of Physics.

Keywords — Computer Simulation, Conceptual Understanding, Electricity, Epistemological Beliefs, FACT, Motivation.

I. INTRODUCTION

Achieving quality education in the Philippines remains a knotty long-term task and continues to baffle all sectors of our society. Every level in Philippine education is crucial as it impacts the development of a quality nation capable of transcending the social, political, economic, cultural and ethical issues that constrain the country’s human development, productivity and global competitiveness. These challenges in turn translate into the mission of producing students who will possess the necessary scientific skills and well-founded epistemological beliefs while possessing the ethical and social consciousness in approaching every course of action; and competent enough to be able to respond to the increasing challenges of the new millennium.

Thus, it would require every aspect of the learning process the capacity of providing a responsive focused-approach in addressing these pressing issues and concerns. The role of educators, therefore, even in the advent of ultra-modern age has never been more important as before. Educators must continue to find ways, devise methods, and employ their own critical-thinking skills to ensure that learning process is at its best and the goals of achieving quality education is held within the realm of reality and certainty.

Physics is 3D-Difficult, Dull and Dumb. This view often results to students being not motivated, uninterested and therefore performs and understands the subject poorly. Students of Physics find themselves to do multitasking and often realized they are not ready for it [1]. This perception, however, negatively impacts students’ achievement and has serious implications for the technical and technological development of the country.

Traditional physics instruction coupled with the perception that physics is 3D, does not normally result in a coherent and consistent conceptual framework for students rather in gross misconceptions and lack of understanding [2]. The lack of understanding and motivation forced students to revert to their preconceptions even if it oftentimes conflicts with science concepts being taught in the classroom. In order to eliminate these preconceptions, constructivist learning theory suggests that students must be confronted with a discrepant event that conflicts with their world view or preconceptions.

Constructivist teaching is based on the belief that learning occurs when learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information. In this study, the 5–E Learning cycle is adopted to exemplify constructivist learning. The 5–E Learning Cycle is a model that promotes scientific inquiry. Each “E” represents part of the process of helping students sequence their learning experience to develop a connection between prior knowledge and new concepts. The teacher serves as a facilitator as students construct new knowledge based on

Vergel P. Mirana, Assistant Professor, Central Bicol State University of Agriculture, Philippines

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thoughtful inquiry and decision making. The 5 “E’s” are as follows: Engage, Explore, Explain, Elaborate, and Evaluate [3]. Computer simulations by itself is useless. In order to make it a powerful learning tool, instruction should be designed to promote scientific inquiry. In this way, the valuable educational potential of computer simulations will help students understand scientific concepts and assist in promoting conceptual change. In addition, computer simulations can provide conflicts on students’ preconceptions that might eventually lead to meaningful learning. The study of Liu, et. al [4] showed that simulation is an excellent venue for students to learn experientially and provides opportunities for students to practice problem solving and psychomotor skills in a safe, controlled environment. It is in many ways more effective than traditional instructional practices like lecture-based and textbook-based in promoting science content knowledge, developing process skills, and facilitating conceptual change.

Simulations allow students to make connections with everyday life experiences [5]. Simulations promote deep learning and allow students to observe processes that are otherwise unobservable [6]. Simulations allow hypothesis testing via prediction of outcomes [7]. These all lead to improve learning outcome [8].

However, teaching without learning can happen in science classrooms. The unfortunate truth is, even with what one perceives as his or her most engaging activity or best teaching moments, instruction can result in little or no gain in conceptual understanding. Even the brightest students can “learn” science for the purpose of passing a test but then quickly revert back to their misconceptions. According to Angelo and Cross [9], “Learning can and often does take place without the benefit of teaching—and sometimes even in spite of it—but there is no such thing as effective teaching in the absence of learning.”

To address this problem, teachers need better ways of determining where their students are in their thinking and understanding prior to and throughout the instructional process. Students need to be actively involved in the assessment process so that they are learning through assessment as well as providing useful feedback to the teacher and other students. Formative Assessment Classroom Techniques (FACT) can be used to spark students’ interest, surface ideas, initiate an inquiry, and encourage classroom discourse—all assessment strategies that promote learning rather than measure and report learning.

Formative assessment has shown to significantly improve student learning by giving them a better understanding. The ultimate goal of formative assessment is to help students develop their own “learning to learn” skills.

Meanwhile, Conley [10] stated that science classrooms should include investigation of students’ epistemological beliefs. Several studies have indicated that students’ epistemological beliefs are related to their learning and content understanding [11]. Epistemological beliefs - beliefs about knowledge and knowing, are important for the development of students’ learning as they reflect an individual views on what knowledge is, how it can be gained, the degree of certainty, and the limits and criteria for determining knowledge [12]. Researches on Epistemological Beliefs have established that students with sophisticated (expert-like) beliefs are likely to perform better at school and university than students with naïve epistemological beliefs.

In teaching sciences, particularly Physics there is a need for instructors to pay attention to the motivational factors of relevance and confidence [13], which can correlate strongly with student performance in both class and laboratory since they determine the amount and quality of effort that the students put forth. According to McDonough [14], motivation of the students is one of the most important factors influencing their success or failure in learning. If the students do not have motivation to participate in the lesson, they cannot focus their attention on the subject, and they cannot establish any connection with the studies done in the school and real life. The challenge for teachers, therefore, is to design instructional strategies that can encourage, develop, and reward these motivational factors. The use of computer simulations and formative assessment guided by constructivist approach can readily provide this requirement, hence, this study.

Specifically, it sought to answer the following questions:
1. What are the effects of the exemplar lessons that features the use of computer simulations, constructivist approach and formative assessment classroom technique on:
   a. Epistemological Beliefs;
   b. Motivation;
   c. Conceptual Understanding?
2. Is there any statistical significant difference on students’ pretest and posttest on Epistemological Beliefs, Motivation and Conceptual Understanding?

II. METHODOLOGY

The study used the pre-experimental single group pretest and posttest study. Four lessons were developed to provide the necessary intervention after the pretest and were implemented using the features; computer simulations, constructivist approach and formative assessment classroom technique. The study was conducted to a group of high school seniors that include seventy-two (72) students of CBSUA-Laboratory High School. The lesson used PhET and other web-based simulations and similar resources. Formative assessments used include: I Think-We Think; A&D Statements; Chain Note; First Word Last Word and Concept Cartoons. The developed lessons covered topics in electricity that consists of Pioneers in the Field of Electricity as Lesson 1; Electrostatics as Lesson 2; Electric Current as Lesson 3 and Electric Circuit as Lesson 4.

The pretest and posttest scores were used to gauge the sophistication of students’ Epistemological Beliefs and measure students’ level of Motivation. The corresponding t-test analysis provided information on whether significant effects exist as a result of the implementation of the lesson run by computer simulations and constructivist approach.

The pretest and posttest result of the Conceptual Test on Electricity provided an analysis on students’ conceptual understanding. Similar t-test result revealed the level of significance establishing a quantifiable effect of the exemplars.
A. Instruments

1. Epistemological Beliefs Assessment for Physical Science (EBAPS) [16]. EBAPS is a forced-choice instrument designed to probe students' epistemologies, their views about the nature of knowledge and learning in the physical sciences, as described below.

<table>
<thead>
<tr>
<th>EBAPS Dimensions</th>
<th>Sophisticated Beliefs</th>
<th>Naïve Beliefs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure of scientific knowledge</td>
<td>Single Coherent System</td>
<td>Collection of isolated Pieces</td>
</tr>
<tr>
<td>Nature of knowing and learning</td>
<td>Self – Constructed</td>
<td>Propagated from Authority</td>
</tr>
<tr>
<td>Real-life applicability</td>
<td>Applicable to the Modern World</td>
<td>Not-applicable to the Modern World</td>
</tr>
<tr>
<td>Evolving knowledge</td>
<td>Knowledge changes with time</td>
<td>Knowledge does not change with time</td>
</tr>
<tr>
<td>Source of ability to learn</td>
<td>Acquired</td>
<td>Innate</td>
</tr>
</tbody>
</table>

To quantify students’ epistemologies, the following scale was used: Extremely Sophisticated 3.5–4.0, Highly Sophisticated 3.4–3.0, Moderately Sophisticated 2.9–2.4, Poorly Sophisticated 2.3 – 1.6 Unsophisticated 1.5 – 0.

2. Science Motivation Questionnaire II (SMQ-II) [17]. The Science Motivation Questionnaire II contains 25 items regarding students’ motivation to learn science. Students respond on a 5-point rating scale of temporal frequency ranging from (0) never to (4) always. The SMQ-II contains five motivation components: intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation. Each component is measured with 5 separate items. The validity and reliability of this instrument was done by the author. To determine the level of motivation before and after the utilization of the developed lessons, the following scale was used: Highly Motivated 4.21-5.00, Moderately Motivated 3.41-4.20, Somewhat Motivated 2.61-3.40, Slightly Motivated 1.81-2.60, Not Motivated 0.00-1.80.

3. Conceptual Test on Electricity. The test contained 50 items that evaluate students understanding of the topics covered based on the table of specifications made. It provided an assessment of the competencies developed after the implementation of the developed lessons. The statistical reliability of this test is determined using Minitab with a computed Cronbach’s Alpha of 0.9489, establishing high internal consistency of the items used in the quiz.

To determine the level of conceptual understanding, the Mean Percentage Scores (MPS) obtained from the test were categorized as Poorly Sophisticated with a mean of 2.22. Nonetheless, the Source of Ability to Learn is interpreted as Highly Sophisticated. After exposure to the developed lessons, the Epistemological Beliefs of the students improved with an overall mean of 2.53, which is Moderately Sophisticated. This change represents student’s recognition that they can construct ideas from what they do. There were two dimensions where changes have been observed, Nature of Knowing and Learning and Real-Life Applicability. Table II summarizes these findings.

<table>
<thead>
<tr>
<th>AREAS</th>
<th>Interpretation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure of scientific knowledge</td>
<td>Poorly Sophisticated 1.81</td>
<td>Poorly Sophisticated 1.9</td>
</tr>
<tr>
<td>Nature of knowing and learning</td>
<td>Poorly Sophisticated 2.23</td>
<td>Moderately Sophisticated 2.77</td>
</tr>
<tr>
<td>Real-life applicability</td>
<td>Poorly Sophisticated 2.28</td>
<td>Moderately Sophisticated 2.51</td>
</tr>
<tr>
<td>Evolving knowledge</td>
<td>Poorly Sophisticated 2.15</td>
<td>Poorly Sophisticated 2.31</td>
</tr>
<tr>
<td>Source of ability to learn</td>
<td>Highly Sophisticated 3.13</td>
<td>Highly Sophisticated 3.15</td>
</tr>
<tr>
<td>All questions on the survey, equally weighted</td>
<td>Poorly Sophisticated 2.22</td>
<td>Moderately Sophisticated 2.53</td>
</tr>
</tbody>
</table>

III. Results and Discussion

Effects of the Developed Lesson on Students’ Epistemological Beliefs, Motivation and Conceptual Understanding

Analysis of the data from pretest and posttest showed significant changes on some dimensions or areas of students’ characteristics being studied. In Epistemological Beliefs for example, only two of the five domains have significant change observed as revealed by the t-test. In Motivation, three areas have significant change out of five. Remarkably, a significant effect is manifested in conceptual understanding and its corresponding mastery level.

a. Effects on Students’ Epistemological Beliefs

Earlier researches, confirmed the clear relations between epistemological beliefs and student learning. It is clear that in learning physics concepts students’ epistemological beliefs are important. The pre-test epistemology of students was categorized as Poorly Sophisticated with a mean of 2.22. Nonetheless, the Source of Ability to Learn is interpreted as Highly Sophisticated. After exposure to the developed lessons, the Epistemological Beliefs of the students improved with an overall mean of 2.53, which is Moderately Sophisticated. This change represents student’s recognition that they can construct ideas from what they do.

On the other hand, Table III shows the test of significant difference of the Pre-Test and Post-Test of the Epistemological Beliefs of the students. The results revealed that Nature of knowing and learning and Real-life applicability significantly improved after implementation of the lessons, with p-values of 0.001 and 0.040, respectively.
Three components of the questionnaire including: Intrinsic Motivation, Self-Efficacy and Self-Determination showed significant changes after implementations of the developed lessons. This result pinpoints the value of learning by doing and the whole process of constructing new ideas by actual manipulation of learning materials. These finding on motivation is similar to the study of Ke [19] where simulations have been found to be effective in motivating students to learn and in facilitating construction of learning and increasing engagement among learners [20].

### c. Effects on Students’ Conceptual Understanding

The conceptual understanding was measured using the performance level of the students in the teacher-made test in Electricity administered as pretest and posttest.

As shown in Table VI, the results of the pretest in conceptual understanding revealed that 34 students (47.22%) obtained an average mastery level, and 38 students (52.78%) obtained a very low mastery level. On the other hand, the results of the posttest using the same treatment and set of questions indicated a significant increase in the performance level of the students as compared to the pretest results. The results were: seven students (9.72%) obtained “low mastery level” while 65 students (90.28%) obtained an “average mastery” level.

### TABLE VI. FREQUENCY DISTRIBUTION OF SCORES AND PERFORMANCE LEVEL IN THE CONCEPTUAL UNDERSTANDING TEST IN ELECTRICITY (N=72)

<table>
<thead>
<tr>
<th>Percentage Score</th>
<th>Pre Test</th>
<th>Post Test</th>
<th>Performance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>96-100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>86-95</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>66-85</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>35-65</td>
<td>34</td>
<td>47.2</td>
<td>65</td>
</tr>
<tr>
<td>15-34</td>
<td>38</td>
<td>52.7</td>
<td>8</td>
</tr>
<tr>
<td>0 – 14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 – 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Furthermore, as shown in Table VII, the conceptual understanding of the students significantly improved after implementation of the developed lessons with a p-value of 0.001.

### TABLE VII. T-TEST OF STUDENTS CONCEPTUAL UNDERSTANDING

<table>
<thead>
<tr>
<th>Mean</th>
<th>Pre Test</th>
<th>Post Test</th>
<th>t-value</th>
<th>p-value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.49</td>
<td>23.25</td>
<td>-10.804</td>
<td>0.001</td>
<td>Significant</td>
<td></td>
</tr>
</tbody>
</table>

Computer simulations, indeed, promote learning by providing a visual aid that supports conceptual understanding, and engages the learner. As Blake and Scanlon [21] stated, simulations do not work on their own, there needs to be some structuring of the interactions with the simulations to increase...
effectiveness. In this study, the use of constructivist approach facilitated the needed structure to make simulations useful and more relevant.

The study of Gokhale [22] supports that the use of computer simulation enhances conceptual understanding, academic achievement and motivation. Simulations provide the opportunities of understanding physical concepts where students can see concepts. It provides the chances of verification, research, discovery, trial and error as though the student is a researcher in an actual physics laboratory.

IV. CONCLUSION

The developed lessons that feature the use of computer simulations, constructivist approach and formative assessment classroom technique did not entirely changed or altered students epistemological beliefs, significant changes were observed along Nature of Knowing and Learning and Real Life simulations, constructivist approach and formative assessment.

REFERENCES


[22] VERGEL P. MIRANA was born in San Jose, Camarines Sur, Philippines on January 21, 1976. He finished his bachelor’s degree as DOST - SEI Scholar and his master’s degree in Physics Education at Bicol University, Legazpi City, Philippines. He is an assistant Professor and has been teaching Physics at Central Bicol State University of Agriculture, Pili, Camarines Sur. In 2009, being the president of the Philippine Physics Society - Bicol Chapter, he coordinated the Philippine Physics Society’s 31st Annual National Seminar-Workshop Convention. His research on teachers’ awareness and preparedness on climate change has been published in the International Cooperation in Education Journal of Naruto University, Japan. His research interest includes environmental awareness, technology integration, 21st century skills, PBL, STEM and use of FACT. Prof. Mirana has presented in various national and international conferences and was awarded as Best Presenter and Best Poster.

