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ENHANCED CONCEPTUAL UNDERSTANDING, 21ST CENTURY SKILLS AND LEARNING ATTITUDES THROUGH AN OPEN INQUIRY LEARNING MODEL IN PHYSICS

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Abstract

The study is grounded in the fact that in Southeast Asia, there are few studies on the effects of authentic, inquiry-based learning, or instruction in the field of Science education. This study investigated the effects of the open inquiry learning model in Physics on the concept and 21st century skill attainment, and learning attitudes of grade 12 students of a state university in the Philippines. The study involved a pretest-posttest experimental design using quantitative approaches. Normalized Hake gain was used to determine the effectiveness of the open inquiry learning model in enhancing the concept attainment of students. Non-parametric test, particularly, Wilcoxon signed ranks test, determined the significant difference between the pre and post-test scores. Net shift in pre-test and post-test scores in Colorado Learning Attitude about Science Survey (CLASS) identified a shift in the learning attitudes of students. The difference between the pre-test and post-test scores of students was found to be significant (Z=-3.927, p=0.000<0.05; Z=-3.387, p=0.001<0.05). Students achieved a high Hake gain (0.82). There was also a positive shift in the learning attitudes of students. Thus, the open inquiry learning model is effective in improving the conceptual understanding, 21st century skills, and learning attitudes of students. Because of its positive effects on students' holistic learning, further promotion of this learning pedagogy is needed, especially in the Philippines setting. A series of professional development programs anchored on this learning pedagogy may be launched to train teachers and pre-service teachers.

Keywords **–** 21st century learning, Hake gain, Learning attitudes, Open-inquiry learning, Philippines, Physics.

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1. Introduction

"Practice in discovering for one's self teaches one to acquire information in a way that makes information more readily viable in problem solving" (Bruner, 1961: page 26 as cited by Jasperson, 2013). This is a famous quotation from Jerome Bruner, who pioneered inquiry-based learning. It is a learning approach that considers students as active learners; students construct knowledge through the discovery process, having prior knowledge and observations as bases (Zion & Mendelovici, 2012; Fernandez, 2017). Inquiry learning is grounded in constructivism. Constructivist learning theory gives emphasis on knowledge cognition as a result of mental processes (Bada, 2015; Jonassen, 1991). Learning happens when students use their prior knowledge or experiences to construct new ones. Learners undergo the following stages in knowledge acquisition: assimilation, accommodation and equilibrium (Dagar & Yadav, 2016). According to Vgotsky in his theory, social constructivism, social interaction plays role in the acquisition of knowledge. The social interaction may involve sharing, comparing and debating among learners and mentors. Role of teacher in social constructivism is alse defined as motivator, guide and resource person and not as a sole source of knowledge (Dagar & Yadav, 2016). The inquiry approach can be classified into structured, guided, and open inquiry approaches. In structured inquiry, students are engaged with hands-on investigations. In this inquiry approach, they are able to develop basic inquiry skills like making observations, formulating hypotheses, collecting and organizing data, making conclusions and inferences, and finding solutions. Structured inquiry, however, is not sufficient for appreciating the nature of Science (Zion & Mendelovici 2012). It is also insufficient in the development of students' critical and scientific thinking and attitudes (Berg, Bergendahl, Lundberg & Tibell, 2003). In guided inquiry, teachers provide only research questions, and the students will construct their own experimental design to answer the research questions (Pizzolato, Fazio, Sperandeo-Mineo, Persano & Adorno, 2014). It is also considered as an intermediary level that can assist students in shifting from structured inquiry to open inquiry (Lunsford, Melear, Roth, Perkins & Hickok, 2007). Open inquiry is considered to be the most complex level of inquiry-based learning. This is where the context of the study is presented by the teacher. But students will decide on the inquiry questions that they are going to work on. Students are involved in identifying their inquiry questions, designing experiments or procedures, redesigning the experiments, and making conclusions (Zion & Mendelovici, 2012). Inquiry approaches have been proven to have positive effects on students' conceptual understanding of Science (Von Secker, 2002; Jasperson, 2013; Alferi, Brooks, Aldrich & Tenenbaum, 2011; Fernandez, 2017). Teaching through inquiry-based learning has improved engagement in science learning and has resulted in a deeper conceptual understanding of scientific concepts. In addition, inquiry approaches have developed students' higher order thinking skills and positive attitudes toward learning Science. Studies claim that inquiry approaches resulted in the development of linguistic, research, process, comprehensive, questioning and reflecting skills (Alameddine & Ahwal, 2016; Wang, Guo & Jou, 2015). Experiencing Physics through inquiry approaches has also resulted in positive learning attitudes (Lindsay, Hsu, Taylor, Sadaghiani & Cummings, 2012; Salter & Atkins, 2013; Wang et al., 2015). On the contrary, Sen and Oskay (2016) found no significant difference in the cognitive and affective attitudes of students between students exposed to the traditional method of teaching and inquiry approach.

There are many factors affecting performance in Physics such as teaching strategies, learning environment, motivation, epistemological beliefs and learning attitudes towards Physics. Investigation of the effects of pedagogies on learning attitudes of students is necessary because learning attitudes toward Physics are found to be a significant predictor of academic success (Akpinar, Yildiz, Tatar & Ergen, 2009; Hendrickson, 1997). According to Guido (2013) in the Philippine setting, students have a negative attitudes toward learning Physics. The reasons behind the negative attitudes of students toward learning are difficulty in computation in problem sets and lack of motivation for class engagement (Guido, 2013). Others attributed negative learning attitudes in Physics to lack of motivation from the teacher, lack of interest in the subject, negative view of the subject, lack of self-confidence and inability to solve Physics problems (Erdemir & Bakirci, 2009; Mamlok-Naaman, Ben-Zvi, Hofstein, Menis & Erduran, 2005; Tadele, 2016). According to Adesoji (2008), results of the study of conventional and traditional teaching methods show that in order to increase the level of attitude and success in learning Physics, new teaching methods and technology need to be implemented in Physics education (as cited by Guido, 2013: page 2090). According to Boyuk and Kaya (2011) discovery learning is better than passive learning; through this, students can associate physical concepts with their daily lives. Hands-on experiments that use simple materials should be developed. Physics instructors should show the students the connection of Physics, technology, and daily life to improve students' attitudes towards Physics lessons and physical experiments (Boyuk & Kaya, 2011).

In addition, the attainment of 21st century skills should also be emphasized when investigating the effects of learning pedagogy. For today's generation to cope with 21st century demands, they should develop the ability to gather information, think critically, apply knowledge, analyze information, comprehend new ideas, collaborate and communicate (Abdullah & Osman, 2010; Basu & Barton, 2007; Sahin, 2009). In the Philippine context, the Department of Education (2016) through the Enhanced Basic Education Act of 2013, expects learners to develop essential skills such as critical thinking, problem solving, communication and collaboration. The 21st century skills involve a) cognitive, b) learning and innovation skills, c) interpersonal, d) intrapersonal, e) leadership and responsibility, f) productivity and inventive thinking, g) digital age literacy and h) effective communication skills (Hamilton, Soland & Stecher, 2013; NCREL & Metiri Group, 2003 Partnership for 21st century skills, 2002). This research is grounded in the definition of 21st century skills according to the NCREL and Metiri Group (2003). They defined the following components of 21st century skills: digital age literacy, inventive thinking, effective communication and high productivity. Digital age literacy is the ability to make use of information technology as a research and communication tool. Inventive thinking is the ability to think and work creatively with others and demonstrate adaptability, self-direction, risk taking, higher order thinking and sound reasoning. Effective communication is the ability to inform, instruct, motivate or persuade using oral, written or non-verbal communication tools. This skill also involves being able to interact and collaborate in diverse environments. High productivity involves effective management of real-world tools and projects to produce results (NCREL & Metiri Group, 2003 Partnership for 21st century skills, 2002).

There is growing evidence that inquiry approaches had positive effects on Science education; however, in Southeast Asia, there are few studies on the effects of authentic, inquiry-based learning or instruction in the field of Science education (Fernandez, 2017). In the Philippines, although inquiry-based teaching has gained attention in the new Science curriculum (Department of Education, 2016; Gutierez, 2015; Danipog, 2018), empirical research on specific practices of inquiry-based teaching and its effect on students learning is lacking (Danipog, 2018). This study is grounded in this research gap. This study encompasses the evaluation of the open inquiry learning model in Physics in terms of its effects on learning attitudes in Science, concept, and 21st century skills attainment. It specifically sought answers to the following questions:

1. Is there a significant difference in the conceptual understanding of students before and after the implementation?
2. Is there a significant difference in the 21st century skills of students before and after the implementation?
3. What components of the Colorado Learning attitude about Science Survey have shifted to expert-like responses after the implementation?

2. Methods

2.1. Research Design

The study involved a pretest-posttest quasi-experimental design using quantitative approaches. It incorporated a one group pre-test post test design. Descriptive statistics described the conceptual understanding, learning attitudes about Science, and 21st century skills of students prior to the implementation. Inferential statistics determined if there was a significant difference in the pre-test and post-test scores of the students.

2.2. Participants of the Study

Cluster sampling determined the participants of the study. Of the 33 participants involved, 10 were female and 23 were male. They were from the Grade 12 senior high school department under the Science Technology, Engineering, and Mathematics track, at a particular state university. This section is under my instruction. The participants did not have experience with open inquiry prior to the implementation of this study.

2.3. Implementation

The respondents of the study were given pre-tests prior to the implementation of the open inquiry learning model. The open inquiry learning model in Physics, as shown in Figure 1, was implemented in the classroom.

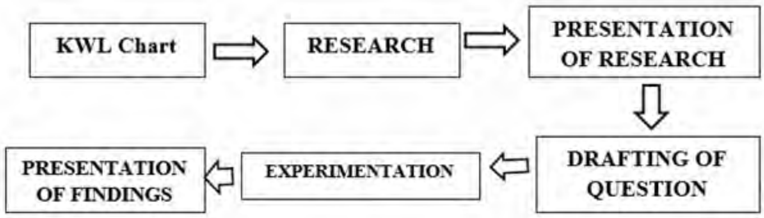

Figure 1. Open inquiry learning model in Physics

These procedures, central to the implementation of the study, helped reframe open inquiry learning. In this learning model, students started with completion of KWL (What I know, What I want to know, What I learned) chart, students wrote what they knew, and what they wanted to know about the topics. After identifying their prior knowledge and what they wanted to know, they did research to answer their inquiries. Students are allowed to do research using their mobile phones in schools. They were also given enough time to complete their research at home where they could have access to the internet. After the completion of their research, students (by group) presented their outputs. Every member was involved during the presentation. During the presentation, the teacher guided them in the discussion. After establishing the concepts of work, power and energy, students were tasked to draft a question that could be answered by experimentation. They completed this stage through collaboration with their groupmates. After identifying their questions, they designed their own experimental procedures, which led them to conclusions. Upon completion of the experiments, students completed their laboratory reports and presented their outputs to the class. Each group presented their experimental designs, results or findings, and conclusions. Any misconceptions during the presentations were addressed by the teacher. Concepts were also summarized at the end of the open inquiry learning model. It took four weeks, equivalent to 16 hours to complete the implementation of the study.

2.4. Research Instruments

The data collection process involved the concept and 21st century skill attainment and shift in learning attitudes about Science, before and after the implementation of the open inquiry learning model. The following instruments served as the main sources of the data.

2.4.1. Energy and Momentum Concept Survey

The Energy and momentum concept survey (EMCS) was adapted in this study to gauge the concept attainment of students. It was developed and validated by Singh and Rosengrant (2003). The concept survey also includes work, power, energy and momentum concepts. In the development of the instrument, Bloom's taxonomy was used to classify the cognitive complexities into three categories such as specification of knowledge, interpretation of knowledge, drawing inferences, and applying knowledge to different situations (Sing & Rosengrant, 2003: page 2). The reliability of the instrument was established with a reliability coefficient greater than 0.80. Momentum questions were excluded in the analysis of the data because the topics on momentum were not covered during the implementation of the study. The

EMCS instrument comes with its own scoring sheet where the answers of the students are encoded. Pre-test and post-test scores in percentage are generated by the scoring sheet.

2.4.2. 21st Century Skill Instrument

The 21st century skill instrument developed by the researcher was used to identify the skills developed by the students. The instrument employed 4 point Likert scale. Five experts in the field of Science education participated in the face and content validity of the study. After incorporating the revisions suggested by the experts, a second round of validation by the experts was conducted. Three students participated in the focus group discussion to further improve the comprehensibility of the study. After the necessary revisions were incorporated, to establish construct validity, it was submitted to pilot testing. To establish the construct validity of the instrument, principal component factor analysis with Promax rotation and Kaiser normalization was used to establish the construct validity of the instrument. Cronbach alpha coefficients were calculated for internal consistency analysis. From 45 questions principal factor analysis resulted in retention of 37 questions, and five constructs. The five constructs of the 21st century skill instrument are a) information literacy, b) inventive thinking, c) effective communication, d) high productivity, and e) leadership. Information literacy is the ability of students to use digital technology in understanding Physics concepts. Inventive thinking is defined as student's creativity and ability to apply the concepts they have learned to create products. Effective communication refers to ability of students to properly communicate their ideas with their groupmates. High productivity is defined as the ability to organize in order to solve specific problems and ability to develop relevant informational materials. The last factor, leadership portrays students' ability to effectively set goals and work in groups (Abaniel, 2017). The 21st century skill instrument in Physics has a Cronbach alpha value of 0.901, thus establishing its internal consistency (Abaniel, 2017). The following are sample statements from the 21st century skill instrument:

Information literacy:

1. I can learn new Physics concepts through surfing the internet.
2. I can organize Physics ideas or information from the internet.
3. I can summarize more information based on my readings from the web.

Inventive thinking

1. I can generate ideas in Physics.
2. I am able to design a Physics experiment.
3. I can make models or products by applying the concepts I learned in Physics.

Effective communication

1. During group activity, I listed to the opinion of others.
2. I am able to communicate my ideas in written reports.
3. I think about a Physics problem and share my ideas with my classmates.

High productivity

1. I can make informative report in Physics.
2. I manage resources efficiently in the completion of our investigation.
3. I can analyze and interpret experimental results.

Leadership

1. I can assign tasks to my groupmates.
2. I work effectively during groupworks.
3. I can easily interact and work with my groupmates during an investigation.

2.4.3. Colorado Learning Attitudes about Science Survey (CLASS)

Colorado Learning Attitudes about Science Survey (CLASS) by Adams, Perkins, Podelefsky, Dubson, Finkelstein and Wieman (2006) was adapted to probe students' attitudes about learning Science. This survey measures students' beliefs about physics and learning Physics and distinguishes the beliefs of experts from those of novice's in the following categories: a) real-world connection, b) personal interest, c) sense making or effort, d) conceptual connections, e) applied conceptual understanding, f) problem solving general, g) problem-solving confidence, and h) problem-solving sophistication. It consists of 42 statements, and students are to respond on a 5-point Likert scale. The validation process of this instrument included face validity-interviews with Physics faculty to establish expert interpretation and construct validity where the survey was administered to 5000 students. CLASS has undergone detailed factor analysis to identify the categories of statements. The principal components extraction with direct oblimin rotation was used in the exploratory and reduced basis factor analysis. CLASS comes with a scoring sheet. The responses of the students were encoded in the scoring sheet. The pre and post test scores and their differences (shift in scores) were automatically calculated by the Excel scoring sheet. Conclusions are made interpretively rather than on a test of significance. Responses were viewed as either agreeing or disagreeing with the expert (expert-like responses).

The following are sample statements from CLASS:

1. A significant problem in learning Physics, is being able to memorize all the information I need to know.
2. When I am solving a Physics problem, I try to decide what would be a reasonable value for the answer.
3. I think about Physics I experience in everyday life.
4. It is useful for me to do lots and lots of problems when learning Physics.
5. Knowledge in physics consists of many disconnected topics.

2.5. Data Analysis

Normalized Hake gain was used to determine the effectiveness of the open inquiry learning model in enhancing the concept attainment of students. The Normalized gain score measures how many more questions a student answered correctly on a posttest out of many they could have possibly improved by. This method removes the limitation on the gain score of a student who does well on the pre-test (Guisti, 2008: page 65).

$$Normalized\ gain\ (< g >) = \frac{Score\ (Posttest) - Score\ (pre-test)}{Score\ (ideal) - Score\ (pre-test)}$$

The following criteria were used to interpret the normalized gain scores (Guisti, 2008):

Normalized gain score	Interpretation
(<g>)> 0.7	High
0.3 < (<g>)≤0.7	Middle
(<g>)≤0.3	Low

Table 1. Normalized gain score and its interpretation

SPSS Version 20 was used to complete the non-parametric tests needed in the study. Related Samples Wilcoxon Signed rank tests were used to identify significant differences between the pre-test and post-test scores of students in a) EMCS and b) 21st century skills test. Net shift in pre-test and post-test scores in CLASS identified a shift in the learning attitudes of students.

3. Results and Discussion

3.1. Effect of Open Inquiry Learning Model on the Concept Attainment of Students

The following tables describe the concept attainment of students on the concepts: Work, power, and energy after the completion of open inquiry learning.

	N	Mean Rank	Sum of Ranks	Z	p
Negative ranks	2	6.75	13.50	-3.927	0.000
Positive ranks	22	13.03	286.50		
Ties	9				

Table 2. Related samples Wilcoxon Signed Rank Test of EMCS pre-test and post-test scores

N	Average Pre-test Score <Pre-test>	Average Post test score <Post-test>	Hake gain <g>
33	21	86	0.82

Table 3. Normalized gains of students after open inquiry learning

Based on Table 2, the result is favorable to the positive ranks, that post-test scores of the students, after being exposed to open inquiry learning, increased. The difference between the pre-test and post-test scores of the students was statistically significant ($Z=-3.927$, $p=0.000<0.05$). Therefore, there was improvement in the conceptual understanding of students after being exposed to an open inquiry learning model. This agrees with the study of Fernandez (2017), the raw scores of pre and post-tests from his study showed that the mean post-test score of experimental group was significantly higher than their mean pre-test score. To further describe the conceptual gain of students, the Hake gain was calculated. The calculated value is 0.81, which is considered as a high Hake gain. The high Hake gain value of students can be explained by their involvement in constructing knowledge. At the start of the framework, students answered what they wanted to know through research. Because they have personally identified or defined the concepts of work, power, and energy, higher retention of the information was evident. The presentation of the results of their research also reinforced their knowledge about the topics. Presentation of their research is essential in this learning model, so that the teacher can address any misconception from the start of the inquiry. In addition, according to Fernandez (2017), inquiry allows students to gain deep conceptual learning of scientific concepts because students are engaged in the work of practicing scientists. Inquiry has the ability to reinforce student learning. In open inquiry learning, students have more opportunities to construct their own knowledge. From the KWL chart to the presentation of the results, the students own their investigation. When students own their investigation, they can give personal meaning during knowledge construction and can identify the relevance of the information that they could easily retrieve (Given, 2002).

3.2. Effects of Open Inquiry Learning Model on 21st Century Skill Attainment

Aside from concept attainment, it is also necessary to investigate on 21st century skill attainment of students. The following table shows the different constructs considered in measuring the 21st century skills attained by the students.

Asymptotic significances are displayed in Table 3. The significance level was set at 0.05. The results of the Related Samples Wilcoxon Signed Rank Test between the 21st century skill pre-test and post-test showed that there is a significant difference in the overall 21st century skill of students ($Z=-3.387$, $p=0.001<0.05$). Therefore, the overall 21st century skills of students improved after the completion of activities under the open inquiry learning model in Physics. The sum of the negative ranks is 91.00, while the sum of the positive rank is 470.00. The observed difference is in favor of the positive rank, showing the improvement of the overall 21st century skills of students. For the factor information literacy, the sum of positive ranks was significantly higher than the sum of negative ranks ($Z=-2.476$, $p=0.013<0.05$). The post-test scores in the factor information literacy were better than the pre-test scores of students. The information literacy skills of students have significantly improved. Information literacy is defined as the ability of students to use digital technology such as computers, internet, and web search engines to understand Physics concepts. During the first phase of the open inquiry learning, students listed down, what they know, and what they wanted to know about the topics: Work, power, and energy. After completing the list, they did research in order to answer what they wanted to know. Most of the students used information technology to access answers to their questions. The open inquiry framework is a constructivist approach. According to Taneri (2010), students in constructivist are encouraged to use inquiry methods to ask questions and investigate a topic using the available resources. We can take advantage of technological advancements. Because of digital technology, knowledge could no longer be considered absolute, education should no longer focus on providing scientific knowledge to students, but it should shift to teaching students how to acquire new knowledge and apply this to practical application to solve problems (Taneri, 2010). Through the open inquiry learning framework, students learned how to construct knowledge from available resources. For inventive thinking, there was a significant difference between the pre-test and post-test scores of students ($Z=-2.960$, $p=0.003<0.05$). Inventive thinking is defined as students' creativity and the ability to create products from the concepts they have learned. Inventive thinking was developed by the students through designing their experimental procedures. A cook-book type experimental procedure was not provided to the students. The students identified their problems and designed the experiments to be able to solve their own problems or questions. Effective communication improved significantly after the implementation of the open inquiry learning approach ($Z=-3.121$, $p=0.002<0.05$). Effective communication is defined as the students' ability to properly communicate their ideas with their groupmates. The learning approach is collaborative in nature. Open inquiry learning adopted a collaborative approach from the first phase of the framework. Students worked by group when they listed what they wanted to know and what they wanted to learn. But they were required to come up with individual research about their topics to ensure active participation of each group member. To succeed in collaborative work, students should be able to properly communicate their ideas to their groupmates. Collaboration enhances communication skills of students because collaboration requires conversation among the participants of the group (Jonassen, 2003).

Factor		N	Rank Average	Sum of ranks	Z	p
a) Information literacy	Negative rank	7	13.57	95.00	-2.476	0.013
	Positive rank	21	14.81	311.00		
	Equal	5				
b) Inventive thinking	Negative rank	6	16.17	97.00	-2.960	0.003
	Positive rank	25	15.96	399.00		
	Equal	2				
c) Effective communication	Negative rank	5	16.30	81.50	-3.121	0.002
	Positive rank	25	15.34	383.50		
	Equal	3				
d) High productivity	Negative rank	9	14.89	134.00	-2.235	0.025
	Positive rank	22	16.45	362.00		
	Equal	2				
e) Leadership	Negative rank	8	10.25	82.00	-3.403	0.001
	Positive rank	24	18.58	446.00		
	Equal	1				
f) Overall	Negative rank	6	15.17	91.00	-3.387	0.001
	Positive rank	27	17.14	470.00		
	Equal					

Table 3. Related Samples Wilcoxon Signed Rank Test between 21st century skill pre-test and post-test

High productivity is the ability of students to organize to achieve their goals of specific problems and the ability to develop relevant informational materials. High productivity skill of students differed significantly after the experimentation (z=-2.235, p=0.025<0.05). An improvement in the high productivity skill of students is evident in the results. The high productivity skills of students were evident in their experimental design and laboratory reports. The relevant informational materials that they developed are their laboratory reports, which included the materials, experimental design, data analysis, and conclusions. The leadership skills of students also improved significantly (z=-3.403, p=0.001<0.05). Leadership is the student's ability to set goals and work effectively in groups. The learning approach is collaborative in nature; thus leadership is needed to effectively collaborate with their groupmates throughout the different stages of open inquiry learning.

3.3. The effect of Open Inquiry Learning Model on Students' Learning Attitudes

Because learning attitude is a significant predictor of academic success, the effect of the open inquiry learning model on the attitude of students was also investigated. The following figure shows the shifts in the learning attitudes of students based on the CLASS categories.

Figure 2 shows the comparison of percentage of expert-like responses. Higher post-test favorable responses were shown in the following categories: sensemaking/effort, problem-solving confidence, problem solving general, real world connection, personal interest and overall learning attitude. On the contrary, there were lower post-test favorable responses in the categories such as: applied conceptual understanding, conceptual understanding and problem-solving sophistication.

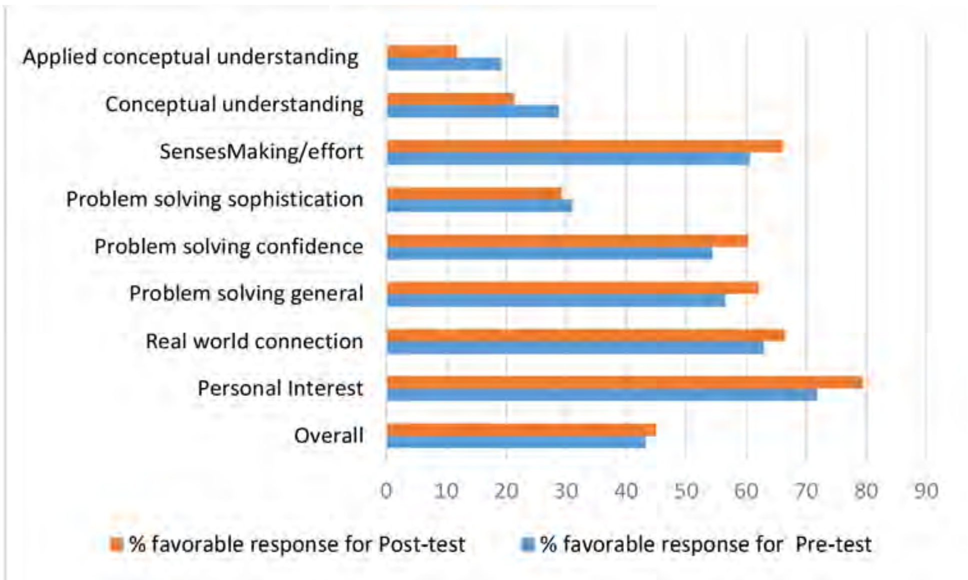

Figure 2. CLASS percent favorable responses for pre and post-test

Categories	Pre	Post	*Shift	Large Shift	Std. Error
Overall	43.2	44.9	1.7		1.8
Personal Interest	71.8	79.3	7.5		4.5
Real world connection	62.9	66.4	3.4		6.1
Problem solving general	56.5	62.1	5.6		3.9
Problem solving confidence	54.3	60.3	6.0		5.0
Problem solving sophistication	31.0	29.3	-1.7		3.7
SensesMaking/effort	60.6	66.0	5.4		4.0
Conceptual understanding	28.7	21.3	-7.5	-7.5	3.2
Applied conceptual understanding	19.2	11.8	-7.4	-7.4	3.1

*Shift-change in attitude of students from novice to expert-like responses

Table 4. Shifts in the learning attitudes of students as measured by CLASS

Table 4 shows that students have shifted their views from novices' to experts' views of Science. There were shifts from unfavorable to favorable responses in the following categories: a) personal interest, b) real-world connection, c) problem-solving general, d) problem-solving confidence, e) sense-making or effort and f) overall. However, negative shifts occurred in the a) problem-solving sophistication, and b) conceptual understanding and applied conceptual understanding. In addition, there were negative large shifts, meaning that the increase in unfavorable responses was more than double the standard error, in conceptual understanding and applied conceptual understanding categories. A positive shift in personal interest could be attributed to the fact that in this learning model, students decided what they would investigate in their research and experimentation. Their curiosity triggered their interest in completing the tasks. There was also a positive shift in the real-world connection construct. According to Zezekwa (2011), students can develop positive attitudes toward learning physics if they are able to develop physics related self-concepts and if physics is linked to everyday life situations or encounter with their environment. This was reinforced during the experimentation phase, where students applied what they had learned from the research and presentations. Through hands-on experiments, they did not deal with abstract concepts but with concrete concepts that they could personally observe. Their designed experiments are also simple and can be related to real-life situations. For problem solving general, a positive shift could be attributed to the students' experience of solving their own mathematical problems. In designing their experiments, they decided what variables to measure and calculate. They were successful in solving the problems involved in their experiments, and because they identified the variables to be calculated, they had a deeper understanding of the variables in the equation, and how they relate to each other. Being able to successfully solve the mathematical problems involved in their experiment enhanced their confidence in problem solving. Thus, a positive shift in the factor problem-solving confidence. For sense making or effort, students thought of the Physics ideas accompanying the Physics equations. For the negative shift in problem- solving sophistication, students still experienced difficulty in solving Physics problems. There was no lecture given to the students prior to the open inquiry learning; they were not given sample problems to guide them. The students were not accustomed to this learning style prior to the implementation of the study. This could have contributed to a negative shift in problem solving sophistication. For conceptual and applied conceptual understanding, students still believed that Physics is consists of disconnected topics and details should be memorized to understand Physics. The reason for this could be the research after the completion of the KWL chart. Since most of the students have consulted the Internet to define and understand concepts, they still believe that these facts should be memorized to understand Physics. The overall attitude of students, have shifted to expert-like responses. According to Schroeder (2010), how students view science is affected by classroom activities. Therefore, a shift from the traditional classroom approach to open inquiry learning improved students' attitudes towards Physics. Instruction that reflects the activities of scientists shifted students' views about science from being absolute to being creative and practical. Open inquiry learning let students work like scientists.

4. Conclusions and Recommendations

The open inquiry learning model in Physics was effective in improving students' conceptual understanding, 21st century skills, and learning attitudes towards Physics. There was a significant difference in the conceptual understanding and 21st century skills of students before and after the implementation of the open inquiry learning model. Students gained a high Hake gain after the implementation. In addition, they also have acquired the following 21st century skills: a) information literacy, b) inventive thinking, c) effective communication, d) high productivity and e) leadership skills. The components of Colorado learning attitude about science survey that have shifted to expert-like responses are: a) personal interest, b) real-world connection, c) problem-solving general, d) problem-solving confidence, e) sense-making or effort and f) overall. However, there were negative shifts in a) problem solving sophistication, b) conceptual understanding, and c) applied conceptual understanding. Because of its positive effects on students' holistic learning, further promotion of this learning pedagogy is needed, especially in the Philippines. A series of professional development programs anchored on this learning pedagogy may be launched to train teachers and pre-service teachers. This will help them learn pedagogy that can orient students with the true nature of Science, improve their conceptual understanding, 21st century skills, and learning attitudes towards Science. The assessment procedures employed in the study can also be adapted in classroom settings, so that assessment will not be confined in measuring concept attainment. Some limitations of the study were: a) small sample size, b) only quantitative methods were used, and c) only one-group pre-test post-test design was employed. Replicated studies may include more participants, or groups. Other constructs such as motivation, and science process skills may also be included in the investigation. Qualitative methods may be employed for more in-depth analyses of the effects of the open inquiry learning model on students' learning.

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