Senior High School Students' learning experience and attainment of 21st century skills in an open inquiry learning framework

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Abstract- — This was an exploratory study to examine whether a specific open inquiry learning framework can be applied in teaching Science courses. The research has employed an experimental design using qualitative research methods. It aimed to investigate the 21st century skills acquired and the learning experience of the students exposed in the open inquiry learning framework. The study involved triangulation of data, data were collected from open-ended questionnaires, focus group discussion and observations. NVivo 11 QSR International was used to increase the analysis transparency, accuracy, efficiency, rigour and trustworthiness. Two categories described 21st century skills attained by the students. They have gained cognitive and interpersonal competencies. Three categories emerged to describe the students learning experience: sources of difficulties, scaffolds of learning and learning opportunities. Sources of difficulties are absence of prior knowledge and experience, group interaction, students' attitudes, experimental design and availability of materials. Scaffolds of learning were identified as internet resources, brainstorming and alternative experiment. The learning opportunities revealed in this study are questioning, research, experiments and presentation. The framework has been effective in the development of 21st century skills and learning of students, thus it should be widely applied in Science instruction.

Index Terms—open inquiry learning, 21st century skills, earth science, NVivo11

1 Introduction

Inquiry-based approach rooted from constructivist approach, where knowledge is considered not to be transmitted directly from teacher to student but is developed by the student-based on their prior knowledge and observation [21]. Students may be exposed to different types of inquiry: guided inquiry, structured inquiry, coupled inquiry or open inquiry. In structured inquiry, teacher provides the questions and procedures. In structured inquiry, students are engaged with hands-on investigation. In guided inquiry, teacher provides only the research question and students will construct their own experiment to answer the question. Open inquiry is however considered to be the most complex level of inquiry based learning. Only the context of the study is presented by the teacher. Students will ask the questions, and will design the experiment to answer their questions [21]. Collaboration with teacher and other students in this approach helps develop students' higher level of thinking [1]. In structured inquiry, students develop basic inquiry skills like making observations, formulating hypothesis, collecting and organizing data, making conclusion and inferences and finding solutions [21]. But this is not sufficient in the development of students' critical and scientific thinking and attitudes [4]. In open inquiry- students face a continuous decision making through-out the inquiry process, from identifying their inquiry questions, designing the experiment and procedures, redesigning the experiments and making conclusions. This method also demands high-order thinking capabilities like questioning, designing an experiment, critical and logical thinking and reflection [21]. They are also expected to develop their psychomotor abilities and behavior. They can develop thinking, deciding, making original implementations [2]. Open inquiry based activities encourages students to achieve higher level of thinking skills and understanding [20]. Students also own their investigation, they are responsible in determining the purpose of their investigation [14].

Chinn and Malhorta presented the difference in the cognitive process of authentic inquiry tasks and simple inquiry tasks. For authentic inquiry students select and invent variables to investigate, they invent complex procedures to address questions of interest, employ multiple controls, incorporate multiple measures of independent , intermediate and dependent variables. In terms of explaining results, observations are repeatedly transformed into data formats, scientists constantly questions the correctness of the results, observations are related to research questions by complex chains of inference, they must judge whether to generalize to situations, employ different forms of argument. In developing theories, in authentic inquiry students construct theories from , coordinate results from multiple studies, and study other scientists' research reports for several purposes. [6].

Pre-service and in service teachers experiencing inquiry curriculum were found to improve their problem solving skills [11]. Inquiry approaches were proven to have developed students' higher order thinking skills and positive attitudes towards learning Science [5]. 21st century framework described the skills, knowledge and expertise students must gain to be prepared in the real world. Students must learn essential skills such as critical thinking, problem solving, communication and collaboration [3]. Furthermore according to Department of Education, Philippines K to 12 Curriculum Guide in Science , at the end of grade 12 the learner should have gained skills in obtaining scientific and technological information from varied sources about global issues that have impact on the country. They should have acquired attitudes that will allow them to innovate and create products useful to community or country. In addition, learners should have made plans related to their interests and expertise considering the needs of their community and country. In the 21st century framework, students must learn essential skills such as critical thinking, problem solving, communication and collaboration. In addition, Hamilton, discussed the 21st century competencies. These competencies are cognitive, interpersonal, leadership and intrapersonal. Cognitive competencies include academic mastery, critical thinking, and creativity. Interpersonal competencies include communication, collaboration, leadership and global awareness. Intrapersonal competencies refer to growth mindset, learning how to learn , intrinsic motivation and grit. [8]. According to the Partnership of 21st century skills (2002) 21st century learner must learn a) core academic subjects, b) interdisciplinary themes, c) innovation skills such as creativity, innovation, critical thinking, problem solving, communication and collaboration and d) information, media and technology, life and career skills.

Although this learning framework is effective in improving skills of students, teachers were found to face difficulties in the implementation of this learning approach. It is inhibited by factors like broad curricular programming which lacks depth, scheduling of time and resources for science and the absence of clear model of inquiry based instructions [19]. There is still confusion about the type of effective science instruction that supports learning of students in open inquiry approach [13]. Many teachers are also hesitant to implement open inquiry learning framework because they were not taught of this strategy during their education undergraduate courses [19]. It was recommended that there is a need for teachers to be provided with models of classroom instructions appropriate for open inquiry learning approach. This study answered this call of researches. The study aimed to attend to the need for teacehrs to be provided with models of classroom instructions appropriate for open inquiry learning approach. It is investigated on the possibility of implementing the open inquiry learning framework to senior high school Science students. It also sought to answer the following questions:

1. How do students describe their learning experience through an open inquiry approach?
2. What are the 21st century skills attained by the students who were exposed to this learning framework?

2 METHOD

2.1. Research design and participants

The research has employed a case-study design using qualitative research methods. This was an exploratory study to examine whether a specific open inquiry learning framework can be applied in teaching Science courses to improve students' 21st century skills and to enhance students' learning experience. Qualitative research methods are appropriate for this study to come up with a complete description of the learning experience of students and the attained 21st century skills. Respondents are grade 11 students under Science Technology Engineering and Mathematics (STEM) Strand in a state university. They are composed of 24 male students and 21 female students. Cluster sampling was used in the selection of the respondents. Earth Science is one of the core subjects offered under this track. The participants were not exposed to open inquiry approach prior to the experiment.

2.2. Instructional Context

The open inquiry learning framework used in the study is in line with constructivism, contextual learning and inquiry learning approaches. The framework was applied to the topic Sources of Electrical energy in Earth Science for STEM Grade 11 students. The intervention was implemented for five weeks composed of one hour session per day. In the first phase of the open inquiry learning framework students were asked to fill up a What I know, what I want to know and What I learned (KWL) chart. The first two columns were completed by the students. After listing what they want to know, I told them to answer their own questions through a research. Students were encouraged to use technology in accomplishing their researches. They were also assigned to complete their researches at home. Their answers to the questions were placed in their activity notebooks. The second phase of the learning framework which I have used, is for students to ask a question which can be answered through an experimentation. The students are also tasked to design and conduct their own experiments to be able to come up with the answers to their own inquiries. The final stage is the presentation of each group. Each group was

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tasked to present their research and their experimental findings.

2.3. Data Collection

The researcher developed open-ended questionnaires for students to describe their experience and their developed skills after the implementation of the learning framework. To provide internal consistency of the questionnaire, specialist in Science education examined the questions. After the implementation of the learning framework, students were asked to answer open-ended questionnaires. To verify their answers to the questionnaires, focus group discussion was implemented. Four focus group discussions were done to further validate students' answers to the questionnaires. Follow up questions were also added to gain profound understanding of the students' responses.

2.4 Data analysis

Students' responses to the open-ended questionnaire were analyzed by content analysis. Content analysis is defined as a systematic and replicable technique in grouping many words into fewer content categories [16]. To manage, code and analyze the data from open-ended questions, Nvivo11-QSR International was used. This software increases the analysis transparency, accuracy, efficiency, rigour and trustworthiness [7]. It also adds to the believability and quality of the analysis [12]. Students' answers to the questionnaires were encoded in the software. Word frequency count in the query tool of Nvivo was used to identify the most common terms mentioned by the respondents, and identify the commonly linked words, synonyms and location of particular terms in the database. Query tool in Nvivo also results to word cluster analysis, tree maps, hierarchy charts and word clouds to provide visual representation of the relationship between codes[10]. Due to the limited nature of automated qualitative analysis, results of word frequency count were further analyzed to identify the terms which are relevant to the research questions and extract meaning of terms. Students' responses were also subjected to autocode tool of Nvivo 11. The resulting nodes and subnodes were further analyzed to identify their relations to the implications of the study as according to Ozkan researchers are the to decide for the data organization and analysis because the way the researchers handle the data assisted by computer analysis add rigor to the study [12].

Focus group discussion results were also subjected to content analysis. Focus group discussions were transcribed, coded and analyzed by the researcher. Manual coding and analyses were done using the following steps: a) familiarization with data and identifying main categories, b) in-depth examination of the data , c) coding pieces of data and grouping them into categories and d) interpretation and synthesis of the organized data to generate conclusions [17]. Inductive method of analyzing focus group discussions was used. Manual coding was used because students answered in Filipino language during the focus group discussions. I read the transcripts, identified open codes based on the transcripts. Open codes were read and reviewed to come up with second level of coding, the axial coding method. Axial codes were further analyzed to come up with categories.

3RESULTS AND DISCUSSION

3.1. 21st Century skills attained by students

Autocode tool in Nvivo11 resulted to twenty-five nodes. The results of word frequency count as shown in the word cloud and the hierarchy charts were further analyzed to come up with nodes or codes, axial codes and categories which are relevant to the research questions of the study.

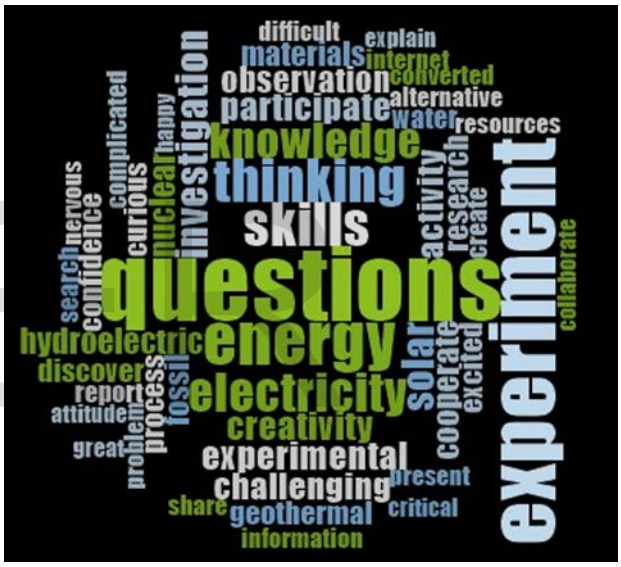

Figure 1: Word cloud describing students' learning experience and 21st century skills attained from the implementation of open inquiry learning framework

Cognitive competencies

In analyzing the data, the open codes investigating skills and observation skills were classified as science process skills. Science process skills are composed of basic processing and integrated science process skills. Basic processing skills include observing, inferring, measuring, communicating, classifying and predicting while integrated science process skills require controlling variables, defining of terms operationally, formulating hypotheses, interpreting data, experimenting and formulating models [9]. Based on the results of classroom observation, most of the students have successfully performed the experiments that they have designed. They analyzed the results of their experiments and made conclusions. Students were observed to design and re-design their experiments when the experiment set-up failed. They have created models

which can show how an electric power plant works. Although it was not evident that they have controlled variables and define terms operationally. The skills that they have acquired in terms of science process skills are confined to observing, measuring, communicating, experimenting and formulating models. Mastery of science process skills will enable students to have deeper understanding of the content they have acquired and will help them acquire content knowledge in the future [9]. Open codes such as create and discover were classified under the axial code creativity. The open inquiry learning framework can foster students' creativity. In this learning framework, students are asked to list down the questions that they want to answer and are tasked to answer their own questions by designing their experiments. They were not provided with a "recipe type" experimental procedures. Aside from the creativity they developed in designing the experiment, they also have shown creativity in coming up with models and videos which can help them explain the inquiry process that they have accomplished. As one student has mentioned " I developed my creativity because I produced my latest video on how to get fossil fuels on my youtube channel pinoy tayo. "

Students also acquired critical thinking skills. One student has answered "Critical thinking because the experiment is hard to make so we have to think carefully to make it successful." As according to Zion open inquiry method demands high order thinking capabilities like questioning, designing an experiment, critical and logical thinking and reflection. [21]. This is supported by Yen who discusses that this method encourages students to achieve higher level of thinking skills and understanding. Students took three class sessions to finally design their experiment. [21]. They carefully thought of which experiment can help them answer their inquiries. They also faced continuous decision making throughout inquiry, experimentation, conclusions and presentations. The science process skills, critical thinking and creativity were further classified into a category: cognitive competency. According to Hamilton cognitive competencies include academic mastery, critical thinking and creativity [8]. These cognitive competencies were gained by the students who were exposed to open inquiry learning framework. It can be implied from the results that students have acquired essential skills such as identifying relevant problem, posing questions and designing an approach to arrive at conclusions [15].

Interpersonal competencies

I identified open codes such as leadership, social skills, participate and collaborate as collaborative skills. A student has mentioned "I think my social skills were developed because I participate and I interact with my groupmates during the experimentation." Another student's argument is as follows: I think the skills that developed in me is the leadership skill of mine cause as a leader my member depends on how I guide them in our investigation." The open inquiry learning framework done in the study is collaborative in nature, the students were assigned to complete the tasks by group. They have assigned their leaders who are responsible for task distribution during the learning process. The group activities in the open inquiry learning framework has given them opportunity to develop their collaborative skills. They were also able to gain communication skills based on the open codes: reporting, present, share and explain. To accomplish the task given to them they have to engage with **their groupmates,** this includes task assignment and participation. They would not have succeeded in this collaboration if they did not communicate well with their groupmates. Communication and collaborative skills of students were developed simultaneously. Aside from communicating with their groupmates, students also developed their communication skills through group presentations. They reported, shared ,presented and explained the results of their researches and experiments to the class. This argument is supported by the following responses of students in the open-ended questions: a) " I think I developed the skill of collaborating or sharing ideas that I think is true and b) I also developed on gaining knowledge and share it confidently in our class. These skills were further classified in the category: interpersonal competency. Interpersonal competencies include communication, collaboration, leadership and global awareness [8].

The following figure portrays the mind-map resulting from the abovementioned analyses:

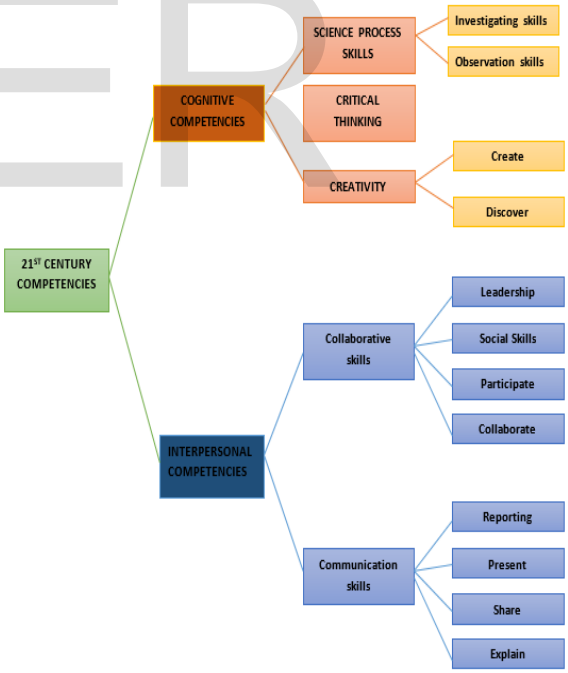

Figure 2. Mind map of the 21st century competencies gained by the students after being exposed to open inquiry learning framework

3.2. Learning experience in Open Inquiry learning Framework

I used manual coding to describe the learning experiences in open inquiry framework. This is based on the focus

Group discussions done upon completion of the learning

process. Manual coding was applied by the researcher because focus group discussions were done in Filipino language. To preserve the meaning of the statements, the answers were analyzed in Filipino language and English open codes were assigned to the terms or phrases relevant to the research questions. I came up with three categories to describe the learning experience of students in open inquiry approach. The following categories emerged: a) sources of difficulties, b) scaffolds of learning and c) learning opportunities.

Sources of Difficulties

Since open inquiry is considered to be the highest form of inquiry, students faced difficulties in completing the learning process. The open codes no prior knowledge, group interaction, experiment design, students' attitude and availability of materials were identified as the sources of difficulties of students. Because the students were not used to open inquiry approach, they had difficulty in designing their experiments. Students are often exposed to structured inquiry where step by step procedures are given to answer a given experimental problem. It took time for the students to design their experiment. One of the statements of students which supported this result is: " At first Ma'am it was difficult, because we had no experience before the experiment but after that, we have learned how to do it properly."

However, having no prior knowledge with the topic helped them draft questions out of curiosity as one participant noted "It is easy to draft questions Ma'am because we are very curious about the topic." Students had difficulty in designing the experiment because not all materials are available in the laboratory , therefore some groups have to redesign and adjust their experiments as to what materials are available in the school. As one student mentioned: " We had a hard time in the experimentation, looking for materials and it was difficult to light the bulb." Classroom atmosphere can be insufficient with regards to data gathering , it is one of the reasons for the difficulty in implementing open inquiry approach among pedagogical deficiencies, lack of motivation , crowded classrooms and safety problems [18]. Group interaction and some students' attitude were also considered to be a source of difficulty. Students were not grouped by peers , therefore some of their groupmates did not actively participate in the experiments, discussions and presentations. One student has stated, "I have a little knowledge on the topic, but I do not know how to manage the group." In doing open inquiry framework it is better to form small groups to increase the participation of the students in the learning activities. Peer grouping is also suggested so that they will be able to work comfortably in their group. These sources of difficulties should be eliminated to take advantage of the benefits of the open inquiry framework.

Scaffolds of learning

I identified the open codes such as internet resources, brainstorming and alternative experiment as scaffolds of learning. Students faced difficulties in the framework , but they were able to find ways on how to accomplish the tasks given to them. Students used their mobile phones for research. Technology especially internet resources have helped them in designing their experiment. Most of the groups have checked for videos of the experiments that they can perform to answer their questions. To also gain knowledge about the topic , they have searched the web for some resources. In this way , they learned about the topics assigned to them. They also redesigned the experiments that they found in the videos to suit the available materials. A student has cited: "It is easy Ma'am, because in experiment once you were able to answer your questions you will be able to create the experiment, there is google anyway." Technology helped students visualize the lesson[19], despite of failing in the experimentation, students were able to answer their queries and make conclusions. Brainstorming also helped them answer their questions and decide which experiment they will perform. This framework required group interaction, so students were able to share their ideas with their groupmates and came up with a decision on what experiment to perform. Alternative experiment has scaffolded learnings of groups which have complicated topics such as nuclear power plant. They were able to come up with an alternative experiment which can model how nuclear power plant works. This group has used the soda and mentos experiment just to simulate the nuclear reaction in a nuclear power plant.

Learning opportunities

It was evident from the focus group discussion that the students have learned in the different phases of the open inquiry framework. The following learning opportunities were identified: a) research, b) experiments, c) presentation and d) questioning. After the students have listed what they know and what they want to know. I asked them to do a research and try to answer the questions that they have written in the column: What I want to know. Students were able to answer their inquiries through research from internet resources and books. According to the students they have learned in the research because they were able to answer their questions. This research activity has opened the opportunity for students to learn how to learn. They were exposed to a learning process which they can do on their own and at their own pace. They were interested to answer their own questions as one student argued: " I am happy because I will answer my own questions and you will discover different methods." From this statement, I can say that students own their investigations, therefore they are more eager to learn about the topics. During the questioning stage, students are already engaged in the science concept and they are prompted to expose their prior knowledge. Prior knowledge are then challenged and created a state of cognitive dissonance resulting to eagerness of the students to understand the concept more profoundly [20]. Another learning opportunity is the experimentation phase of the

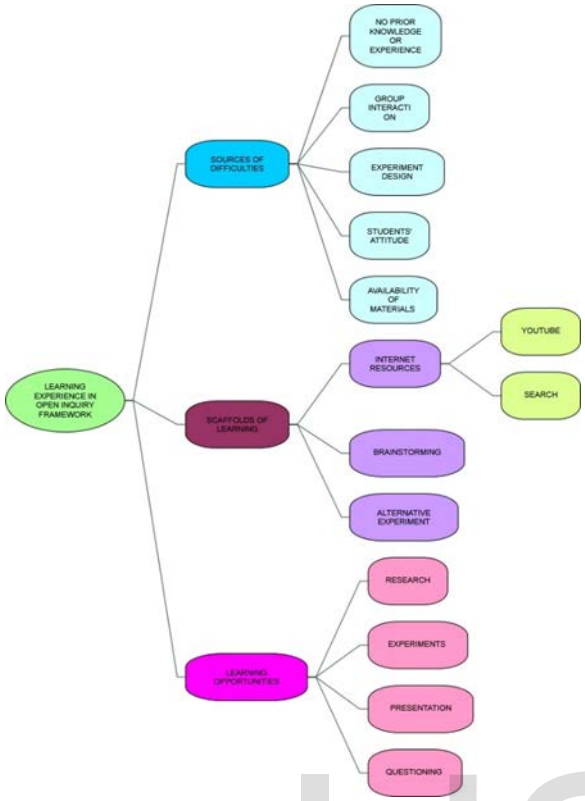

Figure 3. Mind map of the learning experience of students after being exposed to open inquiry learning framework

framework. A student emphasized that he learned during the experimentation because they did the actual observation. One response which can support this is: "I learned in the experiment Ma'am because I was able to know how geothermal power plant works using simple materials." Science is a discipline which can be learned better through hands-on experience or experimentation. The experimentation phase played a very important role for students to have a complete grasp of the concepts because it is the phase where they can manipulate the variables, observe what happens when some variables are controlled and observe how the actual set-up works. Students articulated their thinking during the experimentation and provided for evidence-based explanations [19]. It is also an opportunity for them to redesign the experiment and find out what went wrong in their initial set-ups. Another learning opportunity for the students is the presentation part. Students were assigned to present their findings in the class. According to one respondent: " I learned in the presentation, because you will share whatever you know." The students were obliged to understand the concepts because they have to share it to the class. If they did not try to understand to topics assigned to them , they will not be able to have a successful presentation. Questioning is also considered to be a learning opportunity for students. Some students listen to the questions and answers of their groupmates, in this way they gained knowledge about the topic. " I learned something Ma'am, from the questioning, because my groupmates are asking questions, and they also answered the questions, I listened to them that's how I learned."

4 CONCLUSION

The students who were exposed to open inquiry learning framework developed 21st century competencies such as cognitive competencies and interpersonal competencies. Among the cognitive competencies that they developed are science process skills, critical thinking and creativity. In the science process skills they were able observe, measure, communicate, experiment and formulate models. The framework was also found to foster student's creativity. Students gained critical thinking skills because this learning framework encouraged them to achieve higher level of thinking skills and understanding. Students also developed interpersonal competencies which includes communication and collaboration skills. They had to report, present, share and explain. Communication and collaborative skills of students were developed simultaneously at the different phases of the lesson. They communicated with their groupmates while doing the activities , they also communicated with their classmates when they presented their findings to the whole class. The learning experience of the students was described through identifying sources of difficulties, scaffolds of learning and learning opportunities. Students had difficulties in the learning framework because they had no prior knowledge and experience about the topic and the nature of the activity. They encountered problem with group interaction and students' attitudes because not all members of the group are participating. Experimental design was also a source of difficulty since they had a hard time identifying an experiment which can answer their problem, availability of materials was also a problem which has arouse during the implementation of the framework. Eventhough students had difficulties in this learning framework, they found ways to solve their problems. Internet resources, group brainstorming, alternative experiment scaffolded the learnings of students. Through technology they visualized the topics and the experiment results. Different learning opportunities were identified in this research. Students learned at the different phases of the lesson such as research, experiments, presentation and questioning. Through questioning students were able to outline what they wanted to learn about the topic. Through research using world wide web they have gained knowledge or ideas and were able to answer some of the questions they listed in what they want to know. During the experimentation, students were able to see the actual set-up and had a hands-on experience on manipulating variables to solve their problem. During class presentation, they also learned about the topics and findings of other groups. Presentation is also an opportunity for the teacher to address any misconception presented by the students.

5 IMPLICATIONS AND RECOMMENDATIONS

Open inquiry learning framework helped students gain cognitive competencies such as science process skills, critical thinking skills and creativity. They also gained interpersonal skills such as communication and collaboration. Therefore, this framework should be applied in Science instruction. However, there is still a confusion about the type of effective science instruction that support learning of students in open inquiry approach [13]. The findings of this study helped address this concern. Through this research, we can draw effective strategies to support instruction in open inquiry learning environment. Having no prior knowledge gave spark to students' curiosity about certain topics. A KWL chart can serve as a starting line of the open inquiry learning framework. In this way they will list down what they already knew and what they wanted to know about the topic. They should also be given more opportunities to practice inquiry approaches inside the classroom. At first it was difficult for students but given enough time to practice doing open inquiry, they will get used to it and will no longer be surprised what this strategy requires from them. Sufficiency of laboratory materials for Science should be prioritized. When materials are readily available to the students, they may be able to come up with a more complex investigation of scientific phenomenon. With regard to groupings, I will suggest that students are grouped by peers so that they can work comfortable during the learning process. Formation of small group is also encouraged to aggregate the participation of each group member. Sources of difficulties should be further addressed to highlight the benefits of open inquiry learning. Scaffolds of learning should be provided during the entire learning process. Teachers and students should take advantage of information technology to gain more knowledge and scientific ideas. But students should learn how to evaluate the correctness of the information gained from these resources. Teachers should also be prepared for alternative experiments that students can perform if most materials are unavailable. Students should be given more time for brainstorming so that they can share ideas to their groupmates. There are different learning opportunities found in this research. Thus, teachers who will do open inquiry framework should provide opportunities where students will do: a) questioning, b) research, c) experiment and d) presentation. The use of inquiry should not be confined to experimentation but should be extended to questioning, research and presentation. Teachers should not be discouraged if students failed in the experiment because this is part of the learning process. This will open an opportunity for students to identify and analyze what went wrong in the set-up, inviting them to think critically. With enough practice and motivation, we can provide a Science instruction which can result to students who will gain 21st century skills such as critical thinking, problem solving, creativity, leadership, collaboration and communication.

It is recommended to explore more strategies in line with open inquiry learning approach. Students may also be exposed to presentations of their outputs outside the classroom environment. More groups of respondents can be involved in future studies about this framework. Longer time of tudy is also recommended to have a more profound understanding of how students skills , attitudes changed through the learning framework. Change in the students' perception about nature of science can also be explored in future researches.

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