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Integrating Science Experimentation in Teaching Mathematics: A Lesson Study

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Abstract

Integrated science and mathematics education provide meaningful learning to the students through different strategies such as the use of real-life activities in the classroom. This study focuses on how science experimentation can be integrated in mathematics through process integration approach. To determine how science integration in the teaching of mathematics lesson can be successful, the researchers conducted a lesson study that enables planning, observing, analyzing, and refining the 'research lesson' on integrating the two discipline. Themes on the implementation of the research lesson were identified and were given suggestions to come up with a more established lesson.

Keywords: *Direct variation; Integrative learning; Lesson study; Mathematics education; Science experimentation*

1. Introduction

The integration of Mathematics and Science has long been a subject of discussion in the academic community, as well as being a practice that has been recommended by several educators [1]. To ensure that the learning of Mathematics will be meaningful to the students, it is encouraged that the educators integrate their lessons to other fields. According to the National Research Council [2], integrating science and mathematics will assist the students in developing mathematical understanding and to use mathematics. Moreover, for students to carry out the scientific processes (hypothesis, prediction, observation, etc.), mathematics is required as part of scientific research [3]. Also, students can gain various perspectives, suggest creative ideas in solving problems they encounter in daily life, and transfer the knowledge they acquire in mathematics and science courses through integrated science and mathematics education [4].

Classroom instruction should be integrated so that abstract concepts of Mathematics can be applied to real-life setting. As cited in the study of Jhonson, Riordain and Walshe [5], integrating science and mathematics is thus critical to stimulate and engage students in meaningful and effective learning. Thus, teachers must keep themselves abreast of the needed skills in using scientific concepts in teaching mathematics. In so doing, students will be able to appreciate the beauty of Mathematics and hence, contributing to the successful learning outcomes.

Through the principles of Lesson Study, a research lesson was crafted based from one of the five types of Mathematics and Science integration discussed by Miller, Davison, and Metheny [6] that is, process integration approach. An exploration task was developed that enable the students to delve in scientific processes through experimentation which aims to concretize students' notion of direct variation. This research intends to provide students a different outlook in terms of learning the notion of Direct Variation. Specifically, this study is conducted with the following objectives: (1) to design an exploration task that integrates science experimentation in the teaching of Direct Variation; (2) to analyze how the integration of science experimentation can be effective in helping students learn mathematics, and (3) to examine how the lesson could be improved using the principles of Lesson Study as a tool for evaluating classroom practice.

1.1. Lesson study in mathematics education

Lesson Study (henceforth, LS) is a professional development model for teachers that is long been a practice in Japanese education. It effectively enhances mathematics teachers' quality and promotes teachers' teaching capacity [7, 8].

In detail, LS is a collaborative work done in cycle by group of teachers in the same community of practice who shares specific objectives for lesson planning [9]. The first phase in the LS cycle is the study of curriculum to identify problems and to formulate goals that will become the basis of the selection of topic that will be used for the lesson study [10]. The second phase is the planning and the preparation of a lesson (called a research lesson) that will bring life to the formulated goals [10]. During the lesson preparation, teachers will predict how students will react to specific activities which will require the teachers to reflect on and reassess their teaching approaches (Coenders & Verhoef, 2018). Putting together their individual teaching experiences, their instructional plan is expected to be rich and well-constructed. The third phase is carrying out the planned lesson in a class where one teacher from the group will enact the research lesson while the others will observe and gather evidences on student learning and development. Lastly, the fourth phase is to reflect on and discuss the evidences gathered during the lesson. The teachers will share the data they collected and use it to further improve the lesson, its delivery or its instruction [10].

Several studies [7-9, 11] concluded that teachers who participated in a LS found that it is informative and should be recommended as a tool to improve their teaching and learning of mathematics. Moreover, in a case study conducted by [11], LS enables the teachers to have the opportunity to improve their content and pedagogical knowledge, to assist in understanding the learners, to be collaborative and to network, to reflect on their teaching and to work towards self-improvement, and to develop self-confidence.

Hence, the researchers decided to integrate science experimentation which will provide an avenue for the students to explore the concepts in learning mathematics through the intensive practices of LS.

2. Methodology

Lesson study was chosen as a research methodology because of its power in enabling teachers to improve their instruction. The LS consisted of four main phases: (1) formulating goals (2) planning phase; (3) research lesson; and (4) post-lesson reflection and discussion.

2.1. Formulating goals

The team started with the goal of making mathematics teaching and learning engaging and meaningful to the students. With this in mind, the researchers decided to integrate science in a mathematics lesson. In selecting the topic of the lesson study, the team considered a topic where science experimentation can be integrated. The researchers decided to teach Direct Variation because the topic does not require much pre-requisite lesson.

2.2. Planning phase

The topic chosen for the research lesson was Direct Variation, a lesson from Quarter 2 of Grade 9 Mathematics Curriculum in the Philippines. Learning objectives were drafted based on the competencies specified in the DepEd Curriculum Guide. After several meetings, improvement and modifications of the research lesson were made based from the observations and suggestions of the researchers. A written teaching plan to be used in the actual implementation of the lesson emerges at the end of this phase.

2.3. Research lesson

The research was conducted in a class composed of 15 Grade 9 students from School of Everlasting Pearl Inc., Philippines. The research lesson was delivered by one of the researchers who is a Grade 9 mathematics teacher. The lesson started with the review on solving equations which is an apperceptive basis in solving problems involving direct variation. In introducing the concept of variation, pictures which show relationship between two quantities were presented to the students and they were asked to identify how the quantities are related. Direct variation was introduced to the students through an exploration task that made use of science experimentation which shows the relationship between the mass, volume, and density of the gas.
In preparation for the experiment, students were grouped into three and each group was given a bucket of water, an Erlenmeyer flask, three lighters, a roll of tissue, and an activity sheet. During the experiment, students were asked first to weigh the lighters in a digital weighing scale and record each lighters' initial mass. The Erlenmeyer flask was then filled with water and was inverted and submerged in the bucket of water together with a lighter as seen in Figure 1. As the students press the lever of the lighter, it released gas to the Erlenmeyer flask replacing the water inside. When the gas completely replaced 50 ml of water, the students dried the lighter completely and weigh it again to get its final mass. The procedure was repeated twice using different lighters replacing 100 ml and 150 ml of water in the flask. The students record all the data they have gathered in their data sheet and presented the results in the class.

Fig. 1: The science experiment process

The teacher synthesized the result of the experiment and lead the students to the concept of direct variation and its general equation. Through the synthesis, students figured out that the mass of the gas varies directly with the volume of the liquid and that the density is the constant of variation. During the guided discussion, the students generated an equation that can represent the relationship between the mass, volume, and density of the gas based from the experiment they have conducted. The teacher demonstrated how to translate statements into equation of direct variation and how to solve problems involving direct variation. Due to time constraints, the teacher skipped the part where students will solve direct variation problems independently.

2.4. Post lesson reflection and discussion

The researchers and the observers which consist of graduate students and professors from Philippine Normal University and De La Salle University and teachers from School of Everlasting Pearl, Inc. convened for a post-lesson discussion to underscore the strengths and challenging points observed during the implementation of the research lesson. They expressed main points observed and provided constructive comments and suggestions on how to improve the salient features of the lesson. Reflections from the research lesson were also highlighted.

3. A Results and Discussion

The discussion from the post-lesson conference was able to underscore the research lesson's strengths and weaknesses. The research lesson was planned thoroughly, and majority of the observers highly commended the successful integration of science experimentation in teaching direct variation. However, unexpected factors were noted by the spectators which affect the teaching and learning process. Themes on the implementation of the research lesson were identified and were given suggestions to come up with a more developed lesson. Three valuable perspectives were consolidated and coded, and these are: (1) making smooth connections; (2) power of choices; and (3) probing questions.

3.1. Making smooth connections

The ability of the teacher to make smooth connections from science experimentation to cementing students' notion of mathematical concepts has been emphasized by the observers. One of the main goals of this research lesson is to incorporate science experimentation in developing the understanding of Direct Variation to the students. It is recommended from the insights that since science was integrated in the lesson, it is also important to discuss the underlying concepts that are taking place during the experiment. One of the researchers commented, *"we wanted that this research lesson to be* *multidisciplinary in nature, that is teaching a mathematics lesson through science experimentation. While observing the lesson proper, I think it would be better if the teacher explained the science concepts that are taking place on the experiment and simultaneously highlighting the connections of those phenomena in today's topic, the direct variation. Having this implemented during the activity, you can say that there is indeed an integrated approach."*

Moreover, one of the professors highly appreciated the use of Chemistry in mathematics classroom. She said, *"it is challenging that you incorporated Chemistry in teaching Math. On my part, I think that there is a gap between Math and Chemistry because we use Mathematics in teaching Chemistry but, in Mathematics, it is very seldom to use Chemistry in teaching Math lessons so it's nice, I would like to appreciate that."*

The integration of science experimentation in the lesson was indeed a success because almost all the observers remarked that students were participative and engaged throughout the lesson because they enjoyed the experiment. Also, one of the observers said that, *"the students made a connection between their lesson today and the lessons they have learned from their science class before because they recalled the 'mass- density- volume formula triangle' which they used to help them with their calculations".*

Through the conduct of the science experiment, the students were able to apply mathematics in a real-life situations and connect it to the current lesson. Thus, the lesson concretized students' learning of mathematics, specifically direct variation, with the integration of science.

3.2 Power of Choices

Engagement in LS allows educators to capitalize on the power of choices specifically in quick decision making. These choices will provide a good opportunity for teachers to rectify the mistakes committed in the implementation phase and to improve teaching practices.

As one of the observers, the course lecturer affirms, *"we also go about choices, the choice on what to prioritize in the lesson. It's really a choice and how you are going to defend it. It is only natural that teachers commit mistakes in teaching. But then again, this LS is a good opportunity to rectify those mistakes so that you can further strengthen the knowledge of your students."*

The teacher who demonstrated the research lesson said that her major struggle started on the review part. She acknowledged that she did not actually know the previous knowledge of the student-respondents with respect to solving algebraic equations. Solving equations was actually the recall part of this research lesson and according to the observers and the demo-teacher herself, some of the students had difficulties in solving the items because it took almost 45 minutes before proceeding to the next part of the lesson. Due to this unexpected situation, the demo-teacher decided to allot some time in delving student's misconceptions prior to the review part. The course lecturer noted that the demo-teacher resorted to a metamathematical shift to facilitate the review part of the lesson which is unexpected knowing that the students are struggling in solving the given algebraic equations. The course lecturer asked the demo-teacher during the post-lesson discussion, *"Do you think that it is necessary for you to engage on a mathematical shift given that kind of situation?"* The demo-teacher said, *"I did not expect that I will consume too much time in the review part because the allotted time for that is only 10 minutes. I think the reason for this delay is that students were having difficulty in solving equations particularly the items involving fractions. Hence, to ensure that we will achieve our lesson objectives for this research lesson, I believe that resorting to a mathematical shift given that situation is necessary"*.

The observers also praised the teacher for encouraging her students to help each other such as *"How can you help group 1?", "May I see your solution group 2 and explain it in front of the class so others can understand it also?", "I hope on the next item, everyone will get the correct answer"*, etc. The researchers recognized that a metamathematical shift is necessary given that situation. Quick decisions are also important during the implementation of the lesson. Moreover, due to the unexpected time consumed in the review and motivation part, the demo teacher shared that she already presented this topic in her respective school and the activity went well during her presentation. Before, she teaches direct variation first, and then to be followed by a science experiment. But, the researchers came to an agreement to choose this topic as for the LS provided that this activity will undergo major revisions. According to her, *"in the past, we do the experimentation after the discussion so, it is not actually discovery learning on the part of the students. But in this research lesson, we decided to tweak it wherein we implement the experimentation part first, then we let the students explore the concepts behind the experiment leading to their understanding of the direct variation. In so doing, I believe that there is a big improvement of the original lesson. Moreover, to further facilitate the concept building prior to the experiment, guide questions were added to assess students' understanding."*

Some observers immediately added that it is important that before you give any activity to your students, the teachers must be able to have a first-hand experience prior to the implementation so that student's responses will be anticipated. Hence, the researchers had series of dry-run for this experiment. One of the teachers commented, *"it is important that the teachers have the first-hand experience of their activity before they give it to their students. The purpose is that you anticipate the difficulty of the experiment and, you can estimate the time needed to complete the task. Besides, always expect the unexpected specifically on the actual implementation of the activity."*

One of the researchers mentioned that a very difficult decision making was taken place before the implementation of the lesson because it has been decided to include graphing. But due to time constraint, the researchers decided to focus only in solving direct variation problems.

Lastly, there are also three things that were underscored prior to the decisions that were made during the conduct of the research lesson; (1) sensitivity to both genders (giving both genders equal chances to participate inside the classroom), (2) emphasis on the essential concepts specifically the use of constant, the dependent and the independent variable and (3) being quick when it comes to analyzing student's answers.

3.3 Probing Questions

The way on how teachers probe questions will help students to address their misconceptions. Apparently, conducting LS allows teachers to provide meaningful classroom discussions and reiterate the concepts with more precision.

The teacher facilitated the discussion through a synthesis of the results of the experiment. She randomly asked guide questions to the students based on their observations and analysis of the data they gathered from the experiment. It was noted as a good practice that the teacher is tactful in assessing the wrong answers of the students through art of questioning. This implies that the teacher produced a positive learning environment for the students wherein they have the freedom to express their thoughts and opinions inside the class. The course lecturer said that, *"another thing is the power of probing questions like asking your students 'what could possibly go wrong?', 'what do you think is the error in this solution?', etc. This will help your students to correct their misconceptions. Bring out the strengths and weaknesses and capitalizing on that. Lastly, it is important that we should know what our focus is. Also, I appreciate the way you address students' mistakes by saying that it is okay to commit mistakes as long as you learn from it".* Thus, it can be implied that the way how the teacher asked or probed questions to the students can be a factor why the students were participative and engaged throughout the class hours.

Lastly, the observers noted that it is necessary that in probing student's thinking, the processing of information is critical when it comes to building conceptual understanding. For example, the demo-teacher asked the students to make an equation involving the mass, volume and density. One teacher commented that, *"When you ask your students to make an equation, first you should ask them the constant of variation, the dependent and independent variable and how are they going to establish the relationship among the three. Like, given the constant of variation, if I increase the value of the independent variable, what will happen to the dependent variable?".* In addition, it is affirmed by one of the observers that in solving word problems involving direct variation, the teacher should relate the equation to the previous example from the practice exercise part and form a generalization. The observer argued, *"You should emphasize that a change in the first variable produces an equivalent or opposite effect to the other variable. Show this using your previous example".*

4. Conclusion

The aim of the lesson study is to help teachers observe the learning process happening inside a classroom. It also aids the teachers to visualize the gaps between what they assumed was happening when students learned and what actually happened [12]. With these in mind, the researchers ventured in conducting a lesson study of integrating science experimentation in mathematics. The aim of this lesson study was to observe and analyze the teaching technique involved in the process and how it could be done and furtherly developed and be shared to other teachers. Since, LS is one of the effective interventions for the professional development of the teachers, it provides them the needed competencies to design and deliver instruction that would benefit the learners.

The traditional way of teaching mathematics can be boring to both teachers and students alike. In this regard, incorporating new non-traditional methods and strategies is the ideal way of teaching mathematics. The researchers incorporated science experimentation in teaching direct variation to Grade 9 students. Observations and findings showed that there is a great potential for this teaching method to succeed because it gave the students the freedom to discover learning in a non-traditional and scientific way. Though much were to be improved on the conduct of the lesson especially on the time-constraints, the lesson does really show that mathematics can be learned in a scientific and exciting way.

In completion of this study, there were number of insights that could reflect on. The delivery of the lesson applauded the observers and there were helpful and meaningful suggestions on how the lesson could be refined and on how to integrate effectively in teaching Mathematics. The following were realized during the conduct of the lesson study:

1. Plan the lesson effectively. Although there are some challenges in preparing the lesson, educators must have the open mind to incorporate something new in the lesson. Something that will let the students learn not just to compute but also the concept as well.
2. Allow the students to scrutinize the activity with minimal instructions. To develop the critical and mathematical thinking skills of the students, the teacher should incorporate an activity which involves exploration and must be appropriate to the learners with clear and minimal instructions. At this point, step by step instructions is not that required. Because it is to develop the thinking skills of the students and can come with a conclusion on their own.
3. Implore learners' insights regarding the activity. To ensure that the activity done by the students is clear to them, the teacher can add additional activity by letting them answer questions that will help them to recall and can have potential brainstorming with their members. Oral questioning techniques done by the teacher is also good. It is to help the students express their thoughts in class.

To facilitate meaningful learning of mathematical concepts, integrating science experimentation in teaching mathematics provides promising results especially when it is well-crafted associated to the principles of the LS. Through the observations and reflections from the spectators, the researchers acknowledge that conducting research lesson is a good opportunity to design and present lessons effectively that is deemed beneficial to both the teacher and the students.

With the help of this LS, it gave the teacher researchers a new way and perspective in teaching mathematics and science in an integrated manner. In general, the authors recommend that there must be a continued exploration on how the integration of science experimentation improves mathematics teaching and learning particularly when the concerted practice of the LS is used.

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