Deepening Student's Understanding of Charles' Law Using Theory of Didactic Situation: A Lesson Study

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Abstract: This study explored the use of Theory of Didactic Situation (TDS) in planning and teaching Charles' Law to Grade 9 students. A Lesson Study was conducted to seek how the notion of TDS would enable students to construct meanings out of the milieu designed by the researchers. A science experiment and a hot-air balloon puzzle were used as the milieu. The following results and recommendations transpired: (1) science experiments could be used as powerful milieu, however, it requires a careful planning and considerations on the feedback to allow students' deeper conceptual understanding; (2) given a powerful milieu, the teachers' role is still be significant such as in giving emphasis on the relationships of variables (say, volume and temperature), and providing practice exercises as well as initiating discourse to ensure students' ability in solving problems; and (3) an effective milieu requires meticulous and critical planning that is time-bounded and focused on lesson's objectives. This Lesson Study provided the researchers substantive and insightful conversations on designing and creating milieu for classroom learning which led to revising the milieu to provide students with didactical feedback that would facilitate deeper understanding of science concepts.

Keywords: Theory of Didactic Situation, Charles' Law, lesson study, didactic, a-didactic, science education

1. Introduction

The number of students pursuing Chemistry courses is declining as of 2017 due to students' perceptions that chemistry is a difficult subject (Burke, 2018). Junior high school students in the Philippines have difficulties studying chemistry because it both requires conceptual and mathematical understanding. Students are lacking with basic knowledge in chemistry topics especially in mathematics for calculations, which is a requirement for problem solving. In addressing these difficulties, careful planning of the lesson with well-designed affordances and constraints towards enabling meaningful learning is deemed essential.

Moreover, in addressing students' deficiency in basic knowledge in chemistry especially in mathematics, it is helpful if the students are the one creating ways to make meaning out of the concepts presented. Thus, a Theory of Didactic Situation (TDS) can help teachers in creating and designing learning situations, which would allow students to have a better understanding and learning of difficult concepts. Also, this theory is adaptive to the different learning processes (Artigue, 2000). Without any supervision of the teacher, students can still validate their answers based on the feedback of the situation.

In spite of the potentials of Theory of Didactic Situation, there are limited studies in science education regarding this. This led the researchers to use Theory of Didactic Situation in developing students' deeper understanding in Charles' Law.

A Lesson Study was conducted in order to develop and evaluate teacher's instruction in the classroom where teachers, observers, and researchers gather and discuss how to improve the lesson by sharing multiple perspectives on what actually happened during the lesson (Inprasitha, 2015). It is deemed that intimations on how the designed milieu for this particular lesson could be effectively utilized as a fundamental situation. Lesson Study is able to improve teachers' teaching strategies, research skills, lesson planning, classroom management, self-efficacy, and positive attitudes towards teaching (Ogegbo et al, 2019).

Challenges in Teaching Chemistry

Developing deeper understanding in Chemistry is a challenging task for teachers according to Takbir (2012). In his study the difficulties lie in students' inability to demonstrate a good understanding of very basic concepts of the subject. This result is aligned to the study of Sokrat, Tamani, Moutaabid, and Radid (2014) where difficulties of students in terms of chemical thermodynamics were explored. The difficulties encountered in dealing with chemical thermodynamics are because of students' lack of concentration during the class and lack of basic knowledge, especially in mathematics.

Mathematics skills is important in learning Chemistry because in this subject students are require to solve problems, analyze graphs, and manipulate equations to derive formulas. However, in the results of the study of

Mollanida (2002), it revealed that students' quantitative problem-solving skills in Chemistry was moderately satisfactory. This is because of several difficulties students are facing in Chemistry classroom. Students had difficulties in unit conversion, fundamental operations of mathematics dealing with great numbers, unit equivalents, and the use of systematic procedures in problem solving. In addition, the results of the study of Gojak-Salimović, Korać, Zejnilagić-Hajrić, and Nuić (2018), revealed that students' understanding of concepts in physical chemistry is not at a satisfactory level which is in line with the students' low grades in general chemistry, general physics and mathematics. According to students, the most common challenges they are facing are the lack of time for studying and unclear mathematical concepts.

Theory of Didactic Situation

Students' difficulties in understanding mathematical concepts can be addressed by giving the students a chance to create meaning out of the concepts presented by the teacher. To do this a teacher should design a situation which have both problem whose optimal solution involves the concept in question, and an objective milieu. Milieu refers to any set of instructional material, environment, knowledge available as well as the interaction with others, if any, of the learner. This milieu should provide feedbacks to the students' answers or actions. The students must engage in the milieu by validating their answers or actions, discovering strategies, and to analyze the given feedback from the milieu. This situation is called the adidactic situation named in Theory of Didactic Situation (TDS). Even with almost no input from the teacher, this situation works however; teacher should ensure that students are the ones responsible for solving the problem which is called in TDS the devolution process. After completing the action or answers, the students must develop knowledge by engaging on the milieu. The teacher's task is to help students make connections of their experiences and the established knowledge which is very important to solve other problems. (Hersant & Perrin-Glorian, 2005)

Milieu

Students' interaction to the designed milieu is called adidactic process. A milieu should give feedbacks to students to help them validate their understanding and to create meaning out of it even without the teacher's input. However, in an ordinary classroom discussion, didactic situations are very rare but there are situations that have adidactic potential. This means that a milieu may sometimes provide insufficient feedback to students, so a teacher may have to intervene to modify the milieu (Hersant & Marie-Jeanne, 2005).

The use of Theory of Didactic Situation

González-Martína, Bloch, Durand-Guerrier, and Maschietto (2014) used theory of didactic situation in teaching mathematics in college level. Since the level of difficulty in terms of abstraction and complexity of mathematics increases from secondary school to university level, TDS offers ways in designing and implementing activities that include the significant aspects of mathematics concepts to be dealt with. TDS is useful in making situations for students to face real mathematical questions that will allow them to have authentic mathematical experience like experimenting, and finding solutions and other means of reasoning. Moreover, TDS offers ways to develop questions, activities and approaches that cater high level of abstraction and complexity of knowledge such as connectedness of several topics, great number of problems, the need of previous knowledge, increasing number of work from the students, and the significance of personal initiative.

2. Methods

Lesson Planning

According to the study of Mollanida (2002), Takbir (2012), and Sokrat, Tamani, Moutaabid and Radid (2014) students have difficulties understanding Chemistry topics especially if it includes problem solving, thus the researchers chose Charles' Law as the topic for the lesson study because it will require students both conceptual and mathematical understanding. The researchers wanted to design a lesson that will address both conceptual and mathematical difficulties in chemistry topics. After coming up with the topic, the researchers designed a milieu and explored its potential during the adidactical phase of the lesson. Then, the three objectives were set based on the curriculum guide set by the Department of Education-Philippines. A story about hot air balloon incident was presented to introduce and to catch students' interest in the lesson. Also, unlocking of terms was included based on the researchers' observation to other lesson study presenters; it was found out that defining terms will facilitate easy discussion of the lesson. For the first milieu, the experiment is about the expansion of the balloon. The aim of the experiment is to show how hot air balloons works and also to show the relationship between volume and temperature. The next activity used is to reinforce the student's understanding about the relationship of the two variables. In this activity, an interactive PowerPoint is utilized. For the second milieu, a hot air balloon puzzle serves as an evaluation to check the students' understanding of the lesson. Each puzzle piece contains a problem and an answer on opposite sides. The students need to complete the puzzle by solving the problem and finding its corresponding match.

A dry-run was executed to check the time-boundedness of the lesson specifically, the efficiency of the milieu. Originally, the experiment is about making a model of a hot air balloon, but, that experiment requires greater amount of fire which cannot be done inside the classroom and may have potential risk to the learners. Therefore, another experiment was designed to change the first experiment but will still cover the same concept. The new experiment is about the expansion and contraction of the balloon using hot water and ice bath.

Proper security measures were observed to ensure the proper entry of the students. Also a PowerPoint presentation was design to ensure the seamless flow of the lesson. To ensure classroom readiness, at the start of the demonstration, the compatibility of the presentation was checked with the computer and projector to be used. The chairs were fixed and the materials for the milieus were prepared.

Preparing the Milieu

Experiment: The Expanding Balloons

The objective of the experiment is for the students to determine the relationship between volume and temperature. The expansion and contraction of the balloon is seen by subjecting it to the prepared ice bath and hot water bath. An experiment paper which includes the objectives, materials, safety precaution, procedures and guide questions was prepared to lead the students in performing the experiment.

Hot- Air Balloon Puzzle

The objective of the hot-air balloon puzzle is to enhance the students' skills in analyzing and solving word problems. Each piece of puzzle contains a problem and an answer in its opposite ends. The students will find its match by solving the problem.

The Research Lesson

The teacher starts by ensuring the students' readiness for the lesson. A story about the curious case of Rukuyamu Hot Air Balloon Festival was told to engage students' interest. A hanging question about the case was asked for the students to answer after the lesson. A video about hot air balloon accidents was shown to students to give them the actual view of the case. A laboratory safety measures were introduced using the activity Stop, Look, and Listen. For the grading of the experiment, a rubric is shown and explained by the teacher. The experiment paper which includes the procedure and guide questions as well as the materials for the experiment were distributed to each group. The class was divided into three groups with 4-5 members each. After the experiment, the teacher asked the student to share the results of the experiment. Moreover, probing questions were asked to solicit answers from the students and to emphasize the relationship of the two variables. To deepen the students' understanding of the lesson, a simulation was presented to show the relationship of the variables, volume and temperature. From the simulation, students were asked several questions to come up with the mathematical formula of Charles' Law. The second milieu was then presented in a form of a hot air balloon puzzle. Using the same groups, students solved the puzzle for 30 minutes. Afterwards, the students' answers were checked. Before the class ends, the class went back to the hanging question and answer it.

Post-Conference

The post-conference started with the teacher giving her reflection about the development of the lesson and the behavior of the students. The co-researcher also gave her insights and comments about the demonstration. It was followed by the feedbacks and recommendations of the observers and the professor. Lastly, the evaluation forms from the students were also collected.

3. Results

After the completion of the research lesson demonstration and the synthesis during the post conference between the teacher and the observers, the researchers were able to identify three key ideas that transpired from the lesson study. These key ideas are as follows: science experiments as powerful milieu; importance of teacher's role during the learning process; and time-boundedness and alignment of the activities.

Science Experiments as Powerful Milieu

A powerful milieu should give clear feedbacks to the students. These feedbacks will let the students know whether they are right or wrong. The researchers explored the possibility of utilizing science experiments as a form of milieu. The students performed a simple experiment on 'Expanding Balloons' to observe the relationship between the variables, volume and temperature. During the post-laboratory discussion, students were asked to reflect and infer what transpired during the experiment. An excerpt from the conversation and responses with some of the students during the post-laboratory discussion was:

T: What happen to the balloon when you put it in hot water?

S: It expands

T: Correct! How about the other group, what happen when you put the balloon in the ice bath?

S: Its size become smaller.

From the results of the experiments, students were able to correctly identify the important concept of the lesson: balloon expands when subjected to high temperature and shrinks in low temperature. When students observed that there was no change in the balloon when placed in hot or ice bath, the students automatically searched for the errors that they might commit when doing the experiment. These showed that the experiment itself gives feedback to the students even without the aid of the teacher. At this level, the students start to enter the adidactic phase of the lesson.

However, during the experiment the students have difficulties in distinguishing whether their observations were correct or not since there were no expected results stated in the experiment paper. For it to become a powerful milieu, a clear feedback should be given by the milieu itself. The researchers were able to identify that a table of expected results should be provided by the teacher at the beginning. This revision will enable the designed milieu to be more efficient and powerful. This revision also highlighted the importance of teachers to carefully plan the construction of the experiments and flow of the guide questions. This will ensure that the milieu will give clear feedbacks and will help students develop deeper understanding of the concepts with minimal teacher assistance.

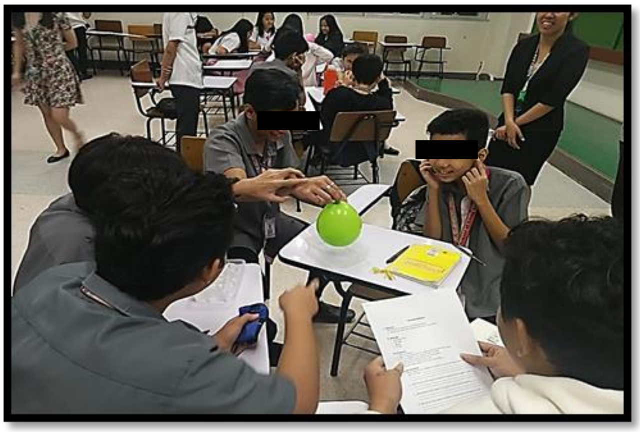

Figure 1. Groups carrying out the experiment, 'Expanding Balloons'. The teacher can be seen observing the students as they try to perform the experiment.

Figure 2. Set-up of the experiment emphasizing what happens to the volume of the balloon when put in an ice bath.

Importance of the teacher's role during the learning process

Although during the adidactical phase of the lesson, the emphasis is the interaction between the learners and the milieu, the researchers' found out that the teachers' role is still deemed important in the learning process. At the beginning, there were challenges in arriving at the relationship between volume and temperature as shown in the students' participation during the post-laboratory discussion. The teacher needs to ask more question to elicit answers and responses from the students. The teacher used the simulation to further highlight the relationship between the variables and to still elicit the answer from the students. Eventually, students were able to identify the relationship between the variables. From this scenario, it evidently shows that the teacher's role is to still be significant, specifically in probing students to arrive with the concept.

In addition, students had difficulties in solving the hot-air balloon puzzle; it took them 30 minutes to finish it. It was found out during the post-conference that (1) there are a lot of problems that made the task tedious and time-consuming to the students; (2) lack of sample problems provided by the teacher hindered the students' readiness in solving the problems; and (3) the variables involved in the formula such as the differences between V1 to V2 and T1 and T2 were not properly introduced.

Time-boundedness and Alignment of the activities

During the research lesson, the teacher as much as possible would like to let the students interact only with the milieu and arrived at the essential ideas based on the milieu's feedback, however, it will entail some time since different students have different pacing of learning as well. It is important that the designed milieu is time-bounded but still aligns with the lesson objectives and competencies. In the research lesson, there were six different problems per group and each group were assigned with different applications of Charles' Law. The teacher, therefore, was not able to thoroughly check all the answers for the hot-air balloon puzzle and process the answers since the students consumed a lot of time in finishing the puzzle. These notes were accounted for in refining the design of the milieu.

Figure 3. The teacher highlighting the relationship between the variables using the simulation.

Figure 4. Students posting their answers of the second milieu (hot air balloon puzzle) on the board.

The researchers were successful in aligning the instruction with the lesson objectives that's why overall, the students were able to gain deeper understanding of the lesson based on the flow of the conversation between the students and the teacher and the evaluation of the students. An excerpt from the conversation and responses of the students during the course of the discussion was:

T: Was it the balloon that expands?

S: No, it's the air inside

T: What do you call the space occupied by the air inside the balloon?

S: Volume

T: What can you say about the volume with respect to temperature?

S: As the temperature increases, volume also increases.

T: What relationship can you observe between the two variables?

S: Direct relationship

Evaluation forms were also given to the students to give feedback about the activities that they went through. This will enable the researchers to take account the personal experiences of the learners. Some of the evaluation of the students were as follows:

S1: 'Effective at konektado yung process sa main topic.' (The process is effective and connected to the main topic.)

S2: 'I like the lesson/topic tackled. I like investigating'

S3: 'I learned something from the activities'

S4: 'Ang cute po at ang creative po nung activities.' (The activities are cute and creative.)

Aligning the objectives of the milieu to the lessons' objective helped students to describe the relationship between volume and temperature which evident in the conversation. Moreover, the objective of the hot air balloon puzzle is also aligned to the lesson objective, thus it strengthens students' understanding in Charles' Law and gives teacher a way to evaluate students' learning.

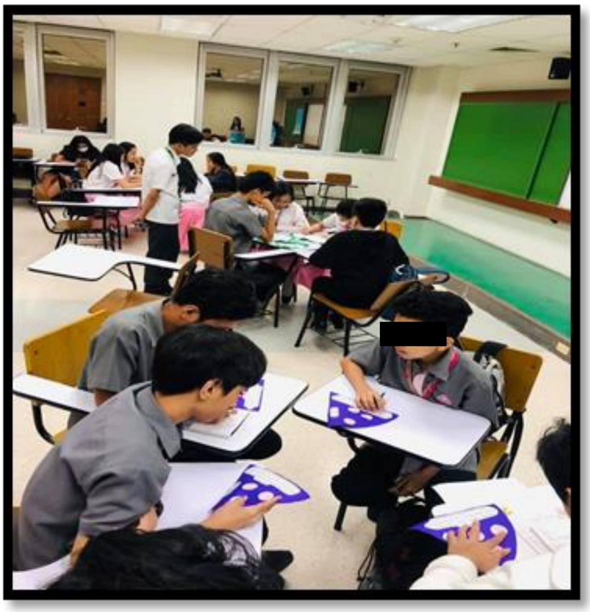

Figure 5. Group of students interacting and discussing with each other about the milieu.

Figure 6. Group of students listening to the teacher as she gives instructions.

Figure 7. Groups of students posting their answers for the second milieu on the board.

4. Conclusion

Students find some chemistry topics difficult since it entails both conceptual and mathematical understanding, however, a careful planning of the lesson and applying some approaches will help augment these dilemmas. This study used Theory of Didactic Situation (TDS) in planning and teaching Charles' Law through a Lesson Study. The following conclusions were drawn throughout the course of the research lesson: (1) science experiments could be used as powerful milieu, however, it requires a careful planning and considerations on the feedback to allow students' deeper conceptual understanding; (2) despite the use of milieu, the teachers' role was discovered to still be significant such as in giving emphasis on the relationships of variables (say, volume and temperature), and providing practice exercises as well as initiating discourse to ensure students' ability in solving problems; and (3) an effective milieu requires meticulous and critical planning that is time-bounded and focused on lesson's objectives.

The designing of milieu played a vital part during the research lesson. It is important that the milieu alone can give a clear feedback once the students entered the adidactical phase of the lesson. Since there were very limited papers of science experiments as a potential milieu, the researchers explored its possibility as a milieu. Also, as much as there should be minimal assistance from the teacher, teacher's assistance is still deemed necessary especially in navigating the lesson and guided facilitation when milieu is given to the students. In addition, since there will be very minimal assistance from the teacher, the milieu designed should still be time-bounded. This is essential since it also develops self-paced learners that has different pacing in learning.

Overall, this Lesson Study provided the researchers substantive and insightful conversations on designing and creating milieu for classroom learning which led to revising the milieu to provide students with didactical feedback that would facilitate deeper understanding of science concepts.

5. Acknowledgement

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