Narrating a Teacher's use of Structured Problem-Based Learning in a Mathematics Lesson

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ABSTRACT

Problem-Based Learning (PBL) is an inquiry method of learning that allows students to process and acquire new information through the use of ill-structured problem that do not have enough information to be solved. This present study implemented a structured PBL approach whereby the teachers guided the students in stages and time allocation was given in each stage, depending on the task. A qualitative design approach was used in this research to investigate the role of the teacher as a facilitator in using a structured PBL. The participants in this study were a class of Year 9 students and a mathematics teacher in a Brunei secondary school. They had previously experienced conducting a typical PBL, however, implementing the structured PBL was a first for them. From the in-class and video-recorded lesson observations, field notes and teacher interview, the results showed that questioning techniques and PBL facts list were used to monitor and guide the students to construct the solutions to the particular mathematics problem. The teacher was able to facilitate students in groups whereby she went to every group to ask questions. Through questioning, the teacher was able to initiate discussions among the students in the group. The PBL facts list on the other hand not only helped the students to be more organised but it was also useful for the teacher to monitor the students' progress.

Keywords: Structured problem-based learning, mathematics, secondary school, qualitative approach

INTRODUCTION

In the traditional teacher-centered and direct instruction teaching approach, teachers can easily focus on the lesson objectives and provide clear explanations to the students. However, the direct instruction offers few opportunities for student-initiated activities and can undermine students' responsibilities for independent learning (Pham, 2011). Problem-Based Learning (PBL) is an approach that can tackle some of the problems or issues in the teaching and learning process in mathematics. PBL is an inquiry method of learning that allows students to process and acquire new information. Teachers can incorporate PBL into learning experience through the use of ill-structured problem that do not have enough information to be solved. In PBL, the teacher acts as a facilitator in making sure the problem directions are thoroughly understood by the students, provide and suggest research sources and facilitate group work that takes place during the lesson (Ronis, 2008).

According to Barrows and Tamblyn (1980), PBL was originally developed in medical school programs and later adapted for the use in elementary and high school settings. Most research studies on PBL have been conducted in tertiary level such as in medical schools and polytechnics. There are also past studies in secondary and even primary level but mainly in the science-based subjects. Very few studies have focused on the implementation of PBL in

secondary mathematics due to perhaps the difficulty in designing a real-life problem context that involves mathematics. The nature of PBL varies depending on the education level, students' capabilities and subjects. The various PBL model has made PBL a flexible and robust pedagogical approach for affording different and unique instructional needs in specific contexts (Hung, 2011).

In this present study, we investigated the issues in implementing a structured PBL in a Year 9 mathematics lesson at a secondary school in Brunei Darussalam that has used PBL as an approach to acquire knowledge and motivate students to learn mathematics.

LITERATURE REVIEW

Most researchers in Brunei agreed that teachers typically teach mathematical concepts through memorization of formula and rote learning (Abdullah et al., 2014; Ang & Shahrill, 2014; Sarwadi & Shahrill, 2014). This direct instruction strategy is fast but students may not be able to grasp what is being taught during the lesson. The students may also not be able to understand fully the lesson and quality time may be wasted even though the time spent is less. However, the students may gain more knowledge and understanding when they discover new knowledge through research activities, investigations and group work. The use of group work and discussions showed great potential in understanding concepts taught in the lessons (Daud & Shahrill, 2014; Sulaiman & Shahrill, 2014).

According to Ebert and Culyer (2011), Vygotsky's idea of learning is an exercise in social interaction because information is acquired from another individual. While Moore (2012) views Vygotsky's idea of learning and teaching as essentially social activities that take place between social actors in socially constructed situations. Both views suggest that Vygotsky's theory focuses on the interactions within the classroom where teaching and learning process takes place. There is a transfer of knowledge from one individual to another through verbal communication and perhaps also through demonstration.

In a classroom, the teacher is expected to be the knowledgeable one but the other students can also have some knowledge and understanding that can help their peers who are in need of explanation and more understanding of the subject matter. Ebert and Culyer (2011) invited teachers to adopt strategies that are not only student-centered but also create spaces for students to verbally elaborate developing concepts that involve a teacher and create a partnership between a teacher and students. When students work on tasks that are open and discovery-based where there are no set of correct answers, they learn that they must share ideas and information if they are to solve the problem at hand (Gillies & Boyle, 2010).

In PBL, students work in small groups to attain the learning objectives. The learning needs of one student complement those of another as the group works together in solving the problems and addressing the learning issues. The small groups become the focus of the learning situations and the teacher becomes the facilitator of each small group (Lambros, 2002). The teacher is expected to guide the students not through instructions but by suggesting and sometimes by giving hints to stimulate students' thinking. The nature of the ill-structured problem context in PBL will allow students to give various possible solutions to the problem. The kinds of problems that students will face in real-world situations are mostly open and ill-structured problems that possess multiple solutions, solution paths, and fewer parameters that are less manipulable (Chin & Chia, 2005). It is a teacher's job to guide the students to get to their groups' solutions to the problems.

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The Present Study

The PBL strategy that was done in the participating school was based on the typical strategy without structure. Teachers gave the problem context to the students and they were left to find the solutions to the problems themselves without guidelines. It took several lessons to accomplish the PBL lesson since the students did the same thing in every lesson right until they presented their findings. There was no time allocation given to the students hence the previous PBL approach was time consuming. This present study is built upon the research study done by Lee and Bae (2007) on implementing a structured PBL strategy in a lesson on volcano. The teachers involved in that study used a structured PBL whereby the teachers guided the students from point A to point B in a heterogeneous class. The structured PBL was designed in stages and in each stage; time allocation was given depending on the task. Even though the PBL lesson was a unit in a science subject, the structured PBL can also be applied to other subjects such as mathematics. The stages of the structured PBL used in the study on volcano were introduction, identifying a problem statement, searching for information, constructing and supporting evidence for a proposed solution, presentation and wrapping up.

In this study, each student will be given a 'Facts List' that contains three blank columns with the headings "What do we know?" "What do we need to know" and "How do we get the information". Additional two blank columns, with the headings "Possible solutions" and "Delegation of tasks" will also require to be filled in by the students. This facts list is the basic document to help the students organize their work during the PBL lesson. Additionally, the facts list was adapted from Lambros (2002) and redesigned by the first author to help the first timers in PBL.

The main concern that a teacher may encounter when using PBL will be that the students are not sure on what to do during the actual PBL lesson. Since the teacher is the facilitator and the students are encouraged to solve the problems by themselves, with fewer instructions by the teacher, the teacher may help the students by using various analytical strategies to encourage students to use problem-solving skills. One strategy may be by using questioning techniques to prompt the students who need help in understanding, defining, formulating or explaining the task in PBL. However, the teacher must make sure that they do not reveal the solution through the questions. Ronis (2008) suggested that the types of questions that teachers can use should be open-ended questions, divergent questions, thought-provoking questions, clear questions and focusing questions. Open-ended questions are questions that have more than one possible answer and cannot be answered with a "yes" or "no". Divergent questions are questions that get students to think about other paths they can take in their thinking and may be answered in several ways. Thought-provoking questions demand insight and reasoning that require both logic and reflection. Meanwhile, clear questions focus on specific phenomena that provide a clear framework for the desired response, and focusing questions are questions that help students to determine the outcomes, sequences, similarities and differences. The teacher may answer the students' question with a question to help the students to think by themselves without the teacher giving them the solutions to the problems directly. Subsequently, the teacher can also ask the students specific questions to help the students achieve success according to the expected goals in the problem-solving process.

The students may learn best by doing more than listening. A PBL approach to learning requires the use of inquiry where knowledge is best acquired through the investigation and resolution of problems. Inquiry and PBL techniques help develop higher-order critical thinking skills that allow students to think logically using information based on sound evidence (Ronis, 2008). PBL therefore, may help students to think logically and use their investigative and research skills to solve problems. They can do this by using the Internet,

reading books and newspaper articles, and even professionals in the area of the subject matter. The students may even resort to ask architects about how they draw plans that use scales or they may ask a banker about interest rates to calculate loans. The Internet is a readily available source of research where students can look up information regarding the problems they need to solve. The inquiry-based nature of PBL may also help to motivate students to learn. According to Wang and Posey (2011), inquiry-based teaching style presents students with a problem to be solved and it increases students' motivation where they are actively involved in the learning process and allows the students to learn the contents on their own.

As the students work together in groups, they will then build a common experience, which in turn assists them in the process of sharing and communicating. The teacher may provide materials and guide the students' focus in PBL. Internet research inquiries, field investigations and team projects are ideal environments for guided inquiry and discovery (Ronis, 2008). Through collaboration of inquiry-based exploration and research, students will also discover new information and share that information to others during group discussion and also presentation.

PURPOSE OF THE STUDY

The purpose of this study is to investigate the role of the teacher as a facilitator in using a structured PBL to support students' learning in mathematics by working together in small groups. The research question sought was "how does a teacher facilitate students learning during a structured PBL lesson?"

METHOD

The qualitative instruments used in this present study were field notes and video recordings for the classroom observations. Interviews were audio recorded and transcribed verbatim for data analysis. The teacher who conducted the PBL lesson was observed to see how the teacher implemented the structured PBL and also assumed the role as a facilitator. A semi-structured interview was conducted after the PBL lessons to probe the teacher's perception on the structured PBL and the issues of implementing PBL in a mathematics lesson. The students were observed by how many the students responded to the tasks and the interaction among members in each group.

A group of students was selected to be the focus group for an interview. A semi-structured interview was used to probe them on the issues of the implementation of PBL and whether they have acquired knowledge after the PBL lesson. Using these multiple sources of data available after the research investigation, all the data reviewed and were codes into themes. The common themes were linked between the observations and interviews with the teacher and the focus group. Qualitative data were analyzed through examining documents, observing students' engagement during the PBL lesson and interviewing participants. The names of the teacher and students used in this study are pseudonyms. Miss Diana, the teacher who conducted the lesson had experience in conducting PBL lessons but it was her first experience in using a structured PBL. The three students who were interviewed comprised of Radiah, Ezuanee and Mukram. They were recommended by Miss Diana and were judged by their presentation results.

RESULTS

In the first PBL lesson, Miss Diana asked the students to arrange themselves in groups pre-assigned randomly by her. Each group consisted of two or three students. Miss Diana made

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sure that the students seated in their respective groups faced each other so that it would be easier for the students to discuss. Each group was provided with a laptop for their research using the Internet, and to prepare a PowerPoint slide for their presentation. During the focus group interview, Radiah, Ezuanee and Mukram, informed the interviewer that they used the laptop by "*Searching about the hotel, the flight time… making the proposal using PowerPoint*".

Miss Diana then proceeded with the lesson by giving a piece of paper that contained the problem context for the PBL lesson to each student, as shown below in Figure 1.

> You are a travel agent working for an international company based in Brunei Darussalam. A British bank officer from United Kingdom needs to attend a business meeting on the 20th and 21st July 2014 here in Brunei. At the same time, he decided to extend his stay until 23rd July 2014 to explore the historical and cultural heritage of the country. Your task is to propose a package tour after his business meeting.
>
> As this is his first time visiting Brunei, he requested for a reasonable price hotel for his stay in Brunei expressing the currency in British pounds.
>
> He also informed that he would need to do a video conferencing on the 22nd July with the Director in UK. Suggest to him the possible time he can make the video conferencing.

Figure 1. The problem context for the PBL lesson

The students' must assume the roles as travel agents in order to propose a package tour for a British banker on a business meeting, and at the same time for leisure in Brunei. Their tasks also included suggestions on return flight times between Brunei and London, hotel for the time of stay, suitable time for a video conferencing with the Director and the exchange rate between British pounds and Brunei dollars. Since it was the students' first time doing PBL, the students appeared confused and lost with the given task. The students looked at each other, shrugged shoulders and asked themselves what they need to do. Since PBL requires the use of inquiry, Miss Diana started with the question "Do you have any questions for me?" Questioning is one way to guide the students to solve the problems in PBL. The questions used in the lessons were mostly to monitor the students' progress and to lead the students to find the best solution to the problems. Below is an excerpt of the interview with Miss Diana in relation to her questioning.

> "*I used a lot questioning techniques, before that I also will check on students' work first to make sure that they know what the question is asking them to do. On the other hand, I give them examples so that it can lead them to think and research more what the questions want…*"

She then asked the questions, "What is it all about?" and "Do you understand the story?" so as to check if the students really understood the problem context. The students seemed to understand but they did not know the meaning of video conferencing. Miss Diana asked, "What is your laptop for?" and "Do you know what is video call?" The students tried to relate the two questions and discussions amongst the groups started. These questions were

intentionally intended to start a discussion among the students. She did not actually give the immediate definition but let the students think and discuss before explaining, "*Video conferencing is like video call but with many people, like in a meeting.*"

Some questions projected by Miss Diana were intended to help the students from making mistakes. Since one of the tasks was to suggest the suitable time for the banker to conduct a video conferencing with his director, the students needed to know the time difference between Brunei and United Kingdom during summer. Since the students might assume that the time difference is eight hours ahead throughout the year, Miss Diana asked, "*What is the weather like in July?*" When one of the groups was asked about the weather in July, they immediately responded, "Summer!" The students knew about the different seasons in the United Kingdom but they were not aware about the daylight saving hour. Miss Diana gave a few minutes for the group to discuss and search from the Internet while she walked to other groups and asked the same questions. When she came back to the earlier group, she asked the same question again, and the students answered "British Summer Time". When asked further what they understood about British summer time, they were able to answer by referring to Wikipedia that explains about the meaning of British summer time and about daylight saving. Miss Diana, in her interview reiterated her observations, as shown in the excerpt below.

> "*...the British summer time, students do not have any idea on that, they only assume adding one hour means the time difference will be 8 hours, but what I did is after explaining, I will ask them to use time converter, and they will realise that the time difference is still 7 hours. So instead of giving them direct answers, I let them explore on their own*".

Miss Diana gave time for the students to do their own research first, discuss and let the students explain in their own words. Miss Diana re-explained to the students for reassurance that they understood the meaning. According to Miss Diana, by questioning the students "*we [teachers] can understand… we will know so far what they have done and what research have they come up with, are they on the right track and to check whether they have misconception on certain things they have researched*".

In order to facilitate the PBL lesson, the PBL facts list, mentioned earlier, was given to each group during the introduction stage of the lesson. This facts list not only assisted the students to be more organized but it also helps the teacher to monitor the students' progress. During the entire PBL lessons, Miss Diana always checked the groups' facts lists that were entered. From there, she could see their progress and identified any mistakes the students made. In one group, the students wrote the flight schedule and ticket prices for return and one-way between Brunei and London in the "What do we need to know?" column. Miss Diana then asked, "What are the differences between return and one-way?" as a way to find out if the students understood the meaning of return and one-way. A return ticket would be reasonable and Miss Diana expected the students to choose a return ticket. Miss Diana explained the meaning of return and one-way rather than asking the students to search the meanings from the Internet. She then suggested using the return tickets rather than putting both return and one-way in their presentation or proposal.

From the facts list, Miss Diana encountered several minor mistakes or unnecessary information, such as incorrect country and reviews from travellers about the hotel. By using the facts list, Miss Diana managed to save time by asking the students what they would need to do and how to get that information. She also emphasized on the delegation of tasks so that the amount of work would be evenly distributed among the members in each group.

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However, the facts list was not sufficient. According to Miss Diana in her interview, a checklist may help the students to construct their solutions to the problems.

> "*For what I did with my other two classes, I did modify a little bit, after I've done with these group of students. What I intend to do is, I ask the student to brainstorm first, after that they will use the structured PBL about what do we know, how do we know, delegation of task, possible solution and how to get the information. I ask the students to do that first, after checking in them, the next lesson I will provide them with a list of checklist. In that checklist I have stated very clearly that they need to show how they get the answer*".

A checklist together with the facts list will indeed help the students to contract their solutions and to save time, hence making the PBL lessons relatively more structured.

DISCUSSIONS

PBL is relatively new in secondary schools in Brunei. The actual use of PBL is commonly devised for students to prepare themselves for careers such as medicine or nursing. Those students are exposed to real world situations with relevant scenarios or situations. The participating school in this present study had previously used a typical PBL approach, which was based on Preechaporn and Tat (2012) in using scenarios to redefine the problem. From that previous experience, the typical PBL approach was time consuming because the teacher had to wait for all the students to complete one scenario at a time and then proceed to the next one.

In this present study, the structured PBL was more flexible where the problem context given to the students at the beginning of the PBL lesson had all the problem scenarios embedded in the context. The students only had to tackle whichever problems they want to solve first in order to precede with the next task. The students were grouped in twos and threes and it was easier for the teacher to facilitate them. The group members were also able to discuss and delegate the tasks equally among themselves. The teacher was able to facilitate students in groups whereby she went to every group to ask questions. Through questioning, the teacher was able to initiate discussions among the students within their groups. Furthermore, she was able to monitor the students' progress and to identify any mistakes and misconceptions on certain tasks they have researched, by using the questioning techniques. By questioning the students, she was also able to initiate discussions among the students, and hence there was collaboration and transfer of knowledge within the groups.

Since the structured PBL approach was newly introduced and was administered for the first time, there is room for improvement. The facts list was found useful when the teacher walked around each group to monitor their progress but a checklist for the students is required. The teacher was not able to help every individual group of students to construct their solutions to the problems. By having a checklist, the students may be able to refer to the requirements as expected by the teacher, help the students to accomplish the tasks with minimal guidance and at the same time, improve their independent learning. The checklist will also help the students to prepare for their final assignment such as writing up a paper work or a presentation. Any relevant questions that may be asked during their final assignment will be answered by the students either mathematically or based on their constructed solutions.

In total, the three PBL lessons amounted to five hours and twenty-five minutes. In addition, the lessons were conducted in the afternoons, which was outside the actual academic school time period. Each lesson took about one hour and forty-five minutes. The usual academic lesson in the participating school takes about fifty minutes. If the three afternoon lessons

were split into the usual academic lesson, it will take about four weeks to complete, provided if the mathematics lessons were assigned twice in a week. Even though the structured PBL lesson took less time compared to the typical PBL lesson, the former approach was still time consuming. Based on the teaching scheme of work, the mathematics topic on 'Time' should be taught in less than four weeks. Due to the time consuming nature of the PBL approach, the mathematics teachers in the participating school were encouraged to use the structured PBL at least once for every term. Moreover, Miss Diana suggested in using the structured PBL as a co-curricular activity of the school under the Maths Fun Club so that the syllabus and scheme of work will not be disrupted.

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