A lesson study to foster prospective teachers’ disposition in STEM education

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Abstract. Fostering students’ dispositions may start with their interest to the topic then spread to another indicator such as persistence, contextual applications, etc. In many conditions, technology can attract students’ interest and turn complexity into a lot easier problem. Therefore, prospective teachers must first be equipped in the use of the latest technology. However, the use of technology in learning must be designed appropriately. Since excess use of technology may negate someone thinking process, even though thinking is every learning main purpose. This research aim to design the appropriate integration between the learning and technology to foster prospective teachers’ mathematical disposition. POM-QM represents technology embedded for the Science, Technology, Engineering, and Mathematics (STEM) learning process. In the conduct, this lesson study starts with planning the chapter design to integrate the technology into learning. Inside the learning implementations, several observers assigned for each group of students to record every activity. From both cycles reflection phase, the chapter design is able to foster students’ interests, contextual awareness, and their appreciation into the topic. Continuous treatment is needed until the dispositions occurs frequently.

1. Introduction

It is appropriate that every student has a positive disposition towards mathematics [1]. As Kilpatrick [2] pointed out, that mathematical disposition is one of the supports of student success in learning. Likewise, National Council of Teachers of Mathematics (NCTM) [3] which states that students' disposition in dealing with mathematics and their beliefs can affect their achievement in mathematics. This positive disposition will encourage students to stay focused on learning [4].

Unfortunately, many students and parents trust on scores, procedural ability, and problem-solving competence more than their trust on thinking processes and dispositions towards mathematics [2]. The emphasis on cognitive aspects can also have negative impact on students' mathematical dispositions, especially for school-age students [5]. Worse, these negative dispositions may carry over until they continue to higher education or to their future job. Therefore, mathematics learning must be specifically designed in such a way to remove students' negative mathematical dispositions.

To design a learning that can foster mathematical dispositions, can start from things related to students’ daily lives or future job, such as technology. Integrating technology such as in the Science,
Technology, Engineering, and Mathematics (STEM) framework is vital, more connected, and relevant for students [6]. In many conditions, technology can turn complexity into a lot easier and more enjoyable. Since its capability to find the solutions of mathematical calculation, the use of computers in learning is taking over the students’ thinking process [7]. As an example, the use of Mathematica software to find the derivatives of complicated functions in calculus course. Another example in elementary school, the use of calculator for simple calculations (e.g. $7 \times 12$). It will only negate the thinking process which is more useful for future knowledge. However, it does not mean that the calculator does not help mathematics learning at all. In various calculations and more complex problems, e.g. numerical methods, the use of calculators greatly helps both thinking and learning process. Therefore, the use of technology in learning must be designed appropriately. Otherwise, it will only cause the misuse of technology in learning by making a negative disposition for the students’ persistence and interest in mathematics.

In order to teach their students according to technological developments, prospective teachers must first be equipped in the use of the latest technology. In this research, we will discuss about appropriate technology integration in linear programming course. To design a preferable STEM learning, it requires precision on integrating technology into certain parts of the topic. Through the stages of lesson study, a design chapter will be designed and implemented in the classroom.

2. Methods
This research conducted in lesson study format with purpose to design a proper integration between technology and the classroom learning. Student divided into two parallel classes, this enable minimum cycle of lesson study.

The lesson study format in this study follows the idea of Yoshida [8]. First stage of lesson study is planning the chapter design. In this paper, the design planned for the first topic and it also reviewed by both lesson study and the topic expert. Second stage of lesson study is to implement the chapter design in the classroom. Several observers assigned for each group of students. The teaching session also written down and recorded in video by a specific person, this will give a more detailed description of events in learning. In the reflecting session, every observer gives feedbacks to revise the chapter design regarding mathematical disposition indicators to achieve, and then repeat the lesson study to the other parallel class. The last lesson plan and chapter design expected to be an ideal outcome besides the students’ mathematical disposition.

3. Result and Discussion
3.1. Result
Since the learning is the first course meeting, it started with an introduction of linear programming. The introduction begins in a unique way, it started with a contextual problem in the first meeting. This is intended so that students explore and try to solve these problems with the knowledge they have. After the contextual problem set is shown, the instructor gives the opportunity to read and understand the problem set. Then the instructor goes around to check the students’ understanding of the problem set. This was also an opportunity for instructors to recall various knowledge about linear programming that they had learned during high school. This recalling process is important as a warm up so that they can be directly connected to the learning [9]. This process is done by repeating keywords in a linear programming, then assessing students’ responses, and guiding them to recall and re-understand.

As can be seen in figure 1, some of the keywords are repeated such as; vertex, maximize, minimize, and profit. This keyword is repeated continuously from the beginning until end of the learning, the understanding is deepened, and instructors ensures all students have an equivalent understanding.

An understanding of vertices in linear programming is a vital one because vertex is a check point for objective functions. Therefore, the vertex keyword is the starting point for rememorizing. After that, move on to the profit keywords along with the maximum keywords become the most repeated, because corresponds to the problem set given.
This understanding and exploration of vertices and profits continues to be deepened, until all students understand that profits can occur in any known vertex. The following in table 1 is a snapshot of the conversation between the instructor and one of the students.

| Instr | Student’s responses                                      |
|-------|----------------------------------------------------------|
| What does the tailors have? | Wool, cotton, and silk                                  |
| And what he wants? | Profits from selling clothes he makes. He makes two models which he will sell at different prices. |
| Why the tailor didn't just make 100 model A clothes? | I think he does not have the material to make clothes that much |
| Why does not the tailor make it all in model A? It is more profitable? | But model B has cheaper production cost. So maybe he should mix it a bit. |

Students are given time to explore and try to solve the given problem with their initial abilities. Even without many treatments, the students able to be solve the problem set by relying on the accuracy of using simple algebraic variables and arithmetic calculations that have previously been studied in secondary schools, some students also use the linear programming method that has been taught in high school. Some groups managed to answer with the right process and solution, while others at least succeeded in making the correct mathematical model. This shows that the connection process in the introduction phase has been going well.

In the next phase, technology, namely POM-QM software, was introduced. Before the learning begins, students have been asked to install the software. In this phase, the chapter design underwent a revision from experts. In the first cycle design chapter, the instructor gives a brief explanation about POM-QM and its use. However, after the reflection stages the instructors leave the students to explore and try POM-QM themselves. Most of POM-QM menus and functions are available to see, those make it easier for students to do trial and error. As Hmelo-Silver [10] opinion that experiential learning is more meaningful and last longer for students' knowledge.

To foster students’ persistence and appreciation of mathematics, they are then given a second problem set. This time they were asked to solve problems with more than two variables, problem that they had never encountered before. This problem leads to the use of simplex method to find the solution. Simplex methods have not yet been taught, but they are expected to explore their initial method limitations by themselves and figure out that POM-QM is able to solve the problem.
All students, even the person who is not usually interested, trying to understand and participate in solving the problem. Interestingly, the students shout cheerfully and seem satisfied for every idea confirmed as true, and they pay attention carefully when explained that their idea was invalid. Those conditions describes that the learning which has been applied can foster perseverance, interest, and flexibility, all is mathematical disposition indicator [3].

To provide a better picture of learning that has been taught in class, the chapter design in this study shown in table 2 below. In table 2, students' responses prediction does not reflect the students' real responses, the column is a prediction of our design. However, the actual learning interactions do not deviate much from the designed learning. Since the instructor plays his role very well to explore and then return to the track that should be.

**Table 2. Chapter design**

| Students’ responses prediction | Instructions/anticipations |
|-------------------------------|-----------------------------|
| **Material** | **Model A (x)** | **Model B (y)** | **Supply** |
| Silk | 2 | 1 | 16 |
| Wool | 1 | 2 | 11 |
| Cotton | 1 | 3 | 15 |
| Profit | 30,000 | 50,000 |

**Mathematical model:**

Maximize Objective \( z = 30000x + 50000y \)

Constraints:

\[
\begin{align*}
2x + y & \leq 16 \\
3x + y & \leq 11 \\
x + 3y & \leq 15 \\
x, y & \geq 0
\end{align*}
\]

- Do trial and error for every POM-QM’s menu
- Explores the linear programming menu
- Explores constraints, variables, objectives, etc.

Together in the group, students think and write various variables, objects, and mathematical models of the given problem.

Let: \( x = \) Model A clothing  
\( y = \) Model B clothing

Introduction

The instructors present a problem in simple contextual linear programming. This phase also warming up students’ memories and understanding about the topic by repeating and exploring some keywords.

Problem:

A tailor has a supply of 16 m of silk fabric, 11 m of wool, 15 m of cotton fabric. He plans to make two clothing models in the following conditions:

- Every A model of cloth requires 2 m of silk, 1 m of wool, and 1 m of cotton.
- Every B model of cloth requires 1 m of silk, 2 m of wool, and 3 m of cotton.

Let the profit of A model clothing is IDR 30,000 / unit and the profit of model B clothing is IDR 50,000 / unit. Determine the amount of each clothing model that must be made in order to obtain the maximum profit.

Note: the mathematics model of this problem is required for every groups. Instructor checks and may assist each group to ensure their responses.

Time prediction: around 15 minutes

Introduce the technology

Direct the students to explore POM-QM application menus (Linear Program, Transportation, etc.).

Time prediction: around 5 minutes
Students’ responses prediction

**Conduct an experiment:**
- Understanding and inputting constraints
- Understanding and inputting variable
- Trial and error in solving the problem given

Instructions/anticipations

**Core activities: Exploration**
Instructor checks every group understanding about POM-QM. If students do not take the initiative to try solving the problems that have been previously given, then they are asked to try it using POM-QM.

Note: the solutions and their ability to use POM-QM is obligatory. Instructor checks and may assist each group to ensure their responses.

Time prediction: around 30 minutes

**Core Activities: Discussion**
Students asked to present their results of the initial linear programming problems. They share findings and interpreting experimental data in groups.

After solution presented, all students are focused to pay attention and discuss the solutions.

Only if not initiated by students, instructor encourage students to explore all the menus and features of POM-QM such as graph panel, dual panel, etc.

Instructor extend the problem into deeper and more detail understandings. Students given critical questions about the problem, such as “Is it possible that the maximum point lies outside the shaded area? Why?”

Time prediction: around 30 minutes

Presents their results in front of the class:

Students shares findings, start from the use of POM-QM menus, such as; inputting constraints; variables; objectives.
Students’ responses prediction

Instructions/anticipations

| Core activities: verifying obtained capabilities |
|------------------------------------------------|
| Instructors provide other problems to solve with POM-QM. The problem consists of similar problem to the initial problem they already solved and extended problem that needs a good understanding of POM-QM features. The problem also plays a role to connect into the next course meetings, simplex method. |

Problems

The cooking demo committee provided 2 types of nutritious powdered food for the participants. Every 400 g, both types of food contain nutrients as follows:

| Ingredient     | Food A | Food B |
|----------------|--------|--------|
| Protein        | 15 g   | 10 g   |
| Fat            | 2 g    | 4 g    |
| Carbohydrate   | 25 g   | 30 g   |

Participants need at least 15 g of protein, 4 g of fat and 30 g of carbohydrate every day. If the price of food A is IDR 15,000 for every 40 g of food B IDR 20,000 for every 400 g, determine the minimum price of food the participants have spent each day.

Time prediction: around 30 minutes

3.2. Discussion

In this chapter design, students divided into six groups consist of four to five persons. The group limited into five person to provide small-group learning as it is more effective to gain focus [11]. Inside the learning, this grouping has proven effectively encouraging discussion, making a more diligent student to take control of their group and explain the given problems. By the reflection we conclude, lecturer still need to check and confirm every group’s idea, therefore students achieves their confidence and persistence to continue their idea, or to align misleading students’ idea, so they don’t get too far but eventually need repeat from the beginning [12].

Students also asked to explain their findings in front of class. Even though students voluntarily explain in front of the class, they still look bashful and showing their unease, despite their explanation and solution is correct. But not all, some students also showing a good confidence in explaining their solution even when hit by a series of questions. Those activity is very needed to improve understandings, critical and creative thinking, and to practice their confidence in front of people which is needed as a teacher in the future [13].

Those unease gesture should not be done by a professional teacher, and those became our special concern as we preparing our prospective teacher to be ready on their future professional job. The concern has become a revision material of the chapter design. Before the core of learning activities, students need to be given understandings of how to be confident in speaking his minds. Another revision is to give students another more challenging problem, using three variables or more that is using simplex method. Those problems could connect their understandings of the use of simplex method.
4. Conclusion
Build upon the result has been discussed, the chapter design is able to foster mathematical dispositions. Some other affective and cognitive skills have been known to be improved. Although student’s confidence and representation still to think about to accommodate in the design, but those still be valid to foster some of the skills.

The other unwritten but proper things to do in the learning is; (1) In linear programming it best if you begin with a problem; (2) Students grouping is making students easy to control and great to encourage discussion; (3) lecturers still need to check and confirm every groups’ work; (4) series of question when students’ explain their work in front of class is needed to improve understandings, critical and creative thinking, also their confidence; (5) connection between chapter also need to design correctly.

5. References
[1] Kandaga T, 2017 Penerapan Model Pembelajaran Time-Token Untuk Meningkatkan Kemampuan Pemahaman dan Disposisi Matematik Siswa SMA Edumatica 7, 1 p. 21–28.
[2] Kilpatrick J Swafford J and Findell B, 2002 Helping Children Learn Mathematics Washington, DC: National Academy Press.
[3] NCTM, 2000 Principles and Standards for School Mathematics 47, 8.
[4] Sylwester R, 1995 An Educatorâ€™s Guide to the Human Brain by Robert Sylwester English La Alexandria, VA: Assn for Supervision & Curriculum.
[5] Maxwell K, 2001 Positive learning dispositions in mathematics ACE Pap. 11, 11 p. 30–39.
[6] Stohlmann M Moore T and Roehrig G, 2012 Considerations for Teaching Integrated STEM Education J. Pre-College Eng. Educ. Res. 2, 1 p. 28–34.
[7] Boyce C J Mishra C Halverson K L and Thomas A K, 2014 Getting Students Outside: Using Technology as a Way to Stimulate Engagement J. Sci. Educ. Technol. 23, 6 p. 815–826.
[8] Yoshida M, 2000, Lesson Study: A case study of a Japanese approach to improving instruction through school-based teacher development., The University of Chicago.
[9] Businskas A M, 2008, Conversations About Connections: How secondary mathematics teachers conceptualize and contend with mathematical connections, Simon Frases University.
[10] Hmelo-Silver C E, 2004 Problem-Based Learning: What and How Do Students Learn? Educ. Psychol. Rev. 16, 3 p. 235–266.
[11] Springer L Stanne M E and Donovan S S, 1999 Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis Rev. Educ. Res. 69, 1 p. 21–51.
[12] Dahlan T Darhim D and Gardenia N, 2019 Students’ Creative Thinking Skills and Anxiety of Mathematics in an Islamic Junior High School Using Brain-based Learning in Advances in Social Science, Education and Humanities Research 253, Aes 2018 p. 74–76.
[13] Gardenia N Herman T and Dahlan T, 2019 PQ4R Strategy (Preview, Question, Read, Reflection, Recite, Review) for Mathematical Communication Ability in Advances in Social Science, Education and Humanities Research 253, Aes 2018 p. 322–327.