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Mathematical Connection of Prospective Mathematics Teachers in Constructing Graph-Based Real-life Problem

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Abstract.
Mathematical connection ability is one of the important abilities that students should have. Connecting real-world problems to mathematical concepts can make learning mathematics more meaningful for students. In everyday life, there is a lot of information presented in graphs. Graphing competence consists of graph interpretation and graph construction. Even though graph construction is a crucial yet neglected skill. From the previous explanation, the purpose of this study is to describe the ability of students to construct a graph based on a real-life problem. This descriptive qualitative study is collected from 37 prospective mathematics teachers in a university. All students had to answer one question about constructing a graph based on a real-life situation given. The result of this study, students' mathematical connection between everyday life and mathematics itself was still low. Using indicators in this study: 10.81% of the students could not represent the real-life situation in the graph that they constructed; 75.68% of the students made graphs but many features of the graphs did not represent the situation well; and 13.51% of the students made more representing graph but some features of the graph did not relevant. Therefore, in mathematics learning the teacher should give more experience to the students to explore everyday life situations using mathematics and encourage students to write their thoughts down so that mathematics becomes meaningful for students.

Keywords: constructing graph-based real-life problem, mathematical connection, prospective mathematics teachers.

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1. INTRODUCTION

Mathematical connection ability is one of the important abilities that students should have. It is not trivial for most students even at the advanced level [1]. When students can make connections with mathematical ideas, their understanding becomes deeper and more lasting [1, 2]. Web of representations that apply to any mathematical concept, that is a way to demonstrate mathematical understanding, some of them are creating a graph and explaining meaning in words [1, 3]. Visualization plays a significant role for which analytic thinking alone cannot substitute in students' thinking [4]. Moreover, the use of multiple representations in the presentation of concepts – numerically, algebraically, graphically, and verbally wherever is possible – so that students understand connections between different representations and develop deeper and more robust understanding of the concepts [4]. García also believes if students have understanding they will be able to make connections between ideas, concepts, theorems, or meaning [5]. Therefore, mathematical understanding can be achieved through mathematical connection and it is necessary in making meaningful learning.

There are two directions of mathematical connection, that are connections between mathematics and real context, and connections between mathematical ideas [3]. NCTM also highlights connection standards that consist of: recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; and recognize and apply mathematics in contexts outside of mathematics [2]. Connecting real-world problems to mathematical concepts can make learning mathematics meaningful for students since they can apply mathematics concepts to solve problems they face in their daily life. Students feel that mathematics is close to them, not abstract as they might think.

There are some studies of mathematical connection between mathematics and real-life, such as: students' skill of connecting mathematics to real-life [6], Students' understanding of mathematical concepts and their real-world application through the use of math journals [7], and analysis of students' mathematical connection in solving math problems [8]. However, the connection between mathematics and real-life problems in constructing graphs is not discussed yet.

In everyday life, there is a lot of information presented in graphs, for instance: daily cases of Covid-19 in Indonesia, stock price, hourly rainfall, etc. In graphing competence, there are two aspects: graph interpretation and graph construction [9]. In constructing a graph, students are required to generate new parts that are not given, whereas interpretation relies on and requires students to react to a given piece of data [10]. This process requires students to not only interpret graph features but also to use the features to design a graph [11]. Despite its crucial role, graph construction is a neglected skill yet [9–12]. Teachers' expertise might be a barrier to the implementation of meaningful practice in graphing competence. Pre-service teachers mostly still have difficulties with graph interpretation tasks [9]. Thus, this study will discuss the mathematical connection of prospective mathematics teachers in constructing a graph based on a real-life problem.

2. RESEARCH METHOD

This study is descriptive qualitative. The data were collected from 37 first year mathematics prospective teachers at a university in Surabaya. All students had to answer one question about constructing a graph based on the information given as follows.

You can make French fries (like in fast-food chain) by buying frozen potato sticks and frying them for 10 minutes in hot oil until golden brown. Next, drain the potatoes to cool them a bit before they are ready to be enjoyed. Sketch a graph of temperature as a function of time and give explanation.

Adapted from Stewart et al [13]

The data were collected using Google Classroom due to pandemic situations and online learning was applied in the class. Students were allowed to search information they needed on the internet or other sources, like freezing temperature of potato sticks, oil boiling points, room temperature, etc. Those answers then were analyzed based on the connection criteria between mathematics and real-life as in Table 1. These criteria are based on the number of relevant mathematics concepts shown in the problem, such as slope, domain, range, x-axis, y-axis, and maximum-minimum adapted from Altay, et al [6].

Table 1: Criteria of the connection between mathematics and real-life in this study.

Level	Description
0	The graph does not fit the problem given.
1	There are more than 2 connections that do not match the problem. The written explanation of the students is less relevant.
2	There are at most 2 connections that do not match the problem. The written explanation of the students is less relevant.
3	The graph fits with the problem given. The written explanation of the students is relevant.

3. RESULTS AND DISCUSSION

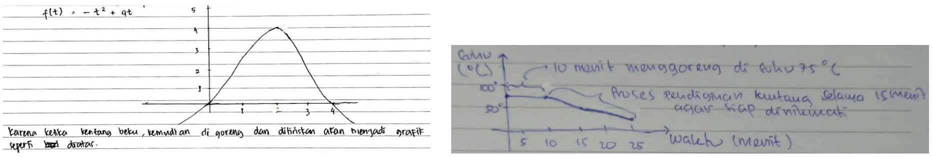
The result of students' answers is summarized in the Table 2.

From Table 2, there are 10.81% students in the level 0. Some of their answers are presented below.

In Fig.1(a), the student failed to fulfill the problem since the student only made a mapping diagram of a function, not a graph that represents the situation in the problem. In Fig.1(b), the assumption of the temperature of frozen potatoes at 0° is not realistic, since the temperature should be below 0°. The constructed graph only provides the

Table 2: The result of students' answers.

Leve	Description	f (%)
0	The graph is not suitable with the problem given.	4 (10.81%)
1	There are more than 2 connections that do not match the problem. The written explanation of the students is less relevant.	28 (75.68%)
2	There are at most 2 connections that do not match the problem. The written explanation of the students is less relevant.	5 (13.51%)
3	The graph fits with the problem given. The written explanation of the students is relevant.	0(0%)



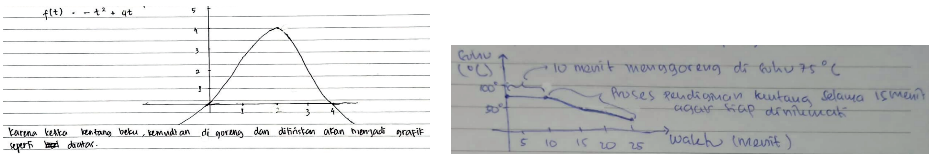
(a) (b)

Figure 1: Some students' answers in level 0. (a). The diagram that was drawn shows a function f with domain {-50,-40,-30,-20,-10,0,10,20}. The range of f is {-20,-10,30,40,50}. When temperature that was needed by the potatoes is higher, the time that was needed is also longer. (b). The graph shows the change of temperature with respect to the period of time for potatoes to be fried.

frying process in the first two minutes. Also, the function formula is not in accordance with the graph. When we look further, the scale of the graph does not correspond with the information given.

From the explanation above, students may face difficulties in connecting features of the graph to real world phenomena including difficulties in understanding graphical representations [12]and lack prerequisite skills such as the basic concepts of mathematics [14]. In this problem such as, frozen potatoes means that the initial temperature should be below 0° (the common temperature of freezer is between -18°C and -20°C), frying potatoes in hot oil for 10 minutes and draining them mean that the domain cannot be negative and should be more than 10 (in x-axis). This is in line with the findings by Roth and Bowen, that to be able to construct and interpret a graph, students (even scientists) have to be familiar with the kind of data or representation modes [15].

Some of the students' answers at level 1 are presented Fig. 2.



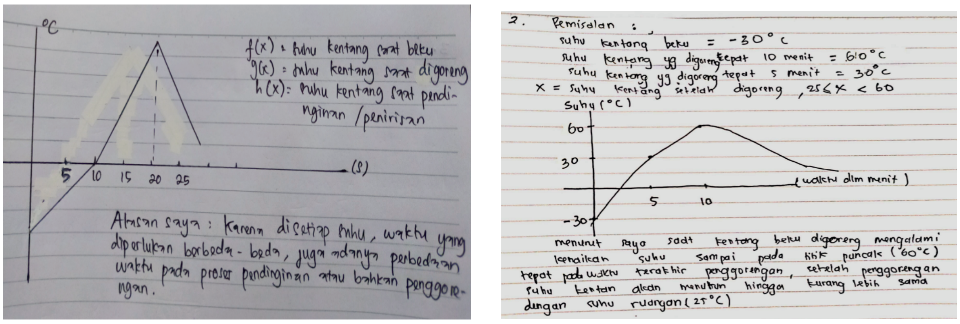
(a) (b)

Figure 2: Some students' answers in level 1.

In Fig.2(a), x-axis should represent time needed to fry potatoes and y-axis should represent the temperature, but the graph is not realistic since the domain (in x-axis) cannot be negative. It is showed by the part of the graph in the left of y-axis. Also, in the graph there is no frying process information for 10 minutes. The temperature should be more than 5. The drained potatoes can't be frozen anymore since they are at room temperature to be enjoyed. The student's assumption of the rate of change when the potatoes were fried and when the potatoes were drained are not realistic. The temperature of the potatoes should rise faster when frying than the temperature drops when the potatoes are drained. This results in the slope of the graph. In Fig.2(b), the graph does not show the process of frying. The graph is not realistic since the temperature of the potatoes is same with the temperature of hot oil (100°C) for the first time. The boiling point of oil should be more than 75°C. The scale of the graph should be improved.

From the explanation above, in Fig.2(a) the student knew that when the potatoes were fried, the temperature would increase rapidly to a certain point until they were golden brown. But, the maximum value in y-axis is 5. It indicates that the student appeared to implement an intuitive idea about narrative, rather than focusing on elements of the graph, such as the meaning of the axes [11]. Students in this level have failed to link the rate of change phenomenon with the mathematical ideas about slope. The graph also through origin. The rate of change when the potatoes were fried and when the potatoes were drained are common mistakes found in this study. This is also one of the common problems stated in [9, 16]. The initial temperature of potatoes (100°C) can be caused by the difficulties in connecting features of the graph to real world phenomena including difficulties in understanding graphical representations [12]. It may be caused by the students' lack of familiarity with the kind of data [15]. Some students in this level also write the formula of the function even though the formula is not relevant with their sketch. This is in line with the findings that the procedural mathematical connection often appears when the students use rules or formulas to complete the graphical tasks [5]. Some of the students' answers at level 2 are presented Fig. 3.

In Fig. 3(a), assumptions of the speed at which the temperature rises when frying potatoes and draining are less realistic. The temperature of the potatoes should rise faster when frying than when the temperature drops when the potatoes are drained. The graph should rise more rapidly during the frying process than the graph decreases during the draining process. The explanations of f(x), g(x), and h(x) are irrelevant with the graph. in Fig.3(b), the explanation of x is the temperature of the potatoes after frying is not fit, because x is the temperature of the potatoes starting from frozen (before frying)



(a) (b)

Figure 3: Some Students' Answers in Level 2. (a). $f(x)$ = the temperature of frozen potatoes $g(x)$ = the temperature of potatoes when it is fried. $h(x)$ = the temperature of drained potatoes. My reason: since in every temperature, the time needed is different. Furthermore, there was time difference in the draining process or even in the frying process. (b). In my opinion, when frozen potatoes are fried, the temperature rises to a peak (60°C) just at the end of frying process. After that, the potatoes temperature will decrease about the same as room temperature (25°C).

until the potatoes are drained. Assumptions of the speed at which the temperature rises when frying potatoes and draining are less realistic. The temperature of the potatoes should rise faster when frying than when the temperature drops when the potatoes are drained. The graph should rise more rapidly during the frying process than the graph decreases during the draining process.

From the explanation above, both of the students did not make the right assumption of the rate of change when potatoes were fried and when drained. This common mistake found in this study could be caused by confusing the slope and the height [9, 16]. Since the students only focused on the temperature at a time but not in the time needed to achieve certain points linked to the information of the given problem.

4. CONCLUSION

The result shows that students' mathematical connection between everyday life and mathematics itself was still low. Most of the students face difficulties in connecting features of the graph to real world phenomena including difficulties in understanding graphical representations, such as domain, range, slope etc. The most common mistake found is connecting slope and the information given. Most students have failed to link the rate of change phenomenon to the mathematical ideas about slope. Some of the students also found to write the function formula that has no correspondence with the problem given. Based on this result, in mathematics learning, the teacher should give more experience to the students to explore every-day life situations using mathematics and encourage students to write down their thinking so that mathematics becomes meaningful for them.

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