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The written mathematical communication profile of prospective math teacher in mathematical proving

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Abstract. Written mathematical communication is the process of expressing mathematical ideas and understanding in writing. It is one of the important aspects that must be mastered by the prospective math teacher as tool of knowledge transfer. This research was a qualitative research that aimed to describe the mathematical communication profile of the prospective mathematics teacher in mathematical proving. This research involved 48 students of Mathematics Education Study Program; one of them with moderate math skills was chosen as the main subject. Data were collected through tests, assignments, and task-based interviews. The results of this study point out that in the proof of geometry, the subject explains what is understood, presents the idea in the form of drawing and symbols, and explains the content/meaning of a representation accurately and clearly, but the subject can not convey the argument systematically and logically. Whereas in the proof of algebra, the subject describes what is understood, explains the method used, and describes the content/meaning of a symbolic representation accurately, systematically, logically, but the argument presented is not clear because it is insufficient detailed and complete.

1. Introduction

Written mathematical communication is an intellectual activity that requires students to express their ideas or mathematical thoughts in writing. Written communication is one of the important aspects [1] that must be mastered by teacher prospective math teacher as tool of knowledge transfer, for at least three major reasons. First, when students communicate their mathematical thinking and reasoning they involve during math instruction, to think, share ideas, and clarify their understanding [2,3]. Second, communication helps teacher to recognize the student's ability, understand their mathematical understanding, and then make appropriate decisions to help them [4]. Third, classroom communication is powerful tool for teacher to assess students' learning and can create a safe environment, exploring ideas, and genuine dialogue [4]. Written communication is commonly used in education to measure how much students absorb the material presented by asking students to write down what they think or understand on the answer sheet. Writing is tool used to describe ideas, relationships, situations, or mathematical arguments, and present abstract ideas in a readable form that can be consumed by others. Thus, written mathematical communication is the process of realizing what is to be conveyed in the form of written. This communication covers all aspects of mathematics including proving as the essence of mathematics [5] because one of the purposes of proving is to communicate statements into deductive systems [6]. Therefore, the mathematical proving must be communicated precisely, coherently and clearly through logical reasoning so that it can be accepted.



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The research about mathematical communication has been investigated in many studies. Dewi [7] studied about the differences in mathematical communication profiles of prospective teachers in solving mathematical problems based on gender and level of math ability using three aspects as the criteria, namely: accuracy, completeness, and fluency. Dewi put more emphasis on the results of mathematical communication; those are the truth of ideas based on mathematical rules, the adequacy of information, and speaking skills, than the process of mathematical communication itself. Furthermore, Wichelt and Kearney [8] conducted research about communication in mathematics learning using open-ended questions. They claimed that students' mathematical vocabulary comprehension was better when using open-ended questions. This study also put more emphasis on the results of mathematical communication, namely mathematical vocabulary comprehension. Kabael [9] studied about the communication skills of math teachers. Kabael found out that junior high school math teachers had no communication skills in the mathematical language as expected of a mathematics teacher. Kabael put more highlighted on the skill of mathematical communication than process. Related to the mathematical proving, many studies have shown that written communication in mathematical proving is a problem to students. Yackel and Hanna [10] found out that developing an understanding of mathematics proof and proving remains a challenge for many students. This is understandable because by its very nature, the mathematical proof is very sophisticated and seems to much more challenging intellectually than many other parts of the school mathematics curriculum. Mathematical proof is one of the most difficult topics for students to learn [11,12]. Moreover, the problem of proof seems to be more complicated because the aim of a problem to prove is to show conclusively that a certain clearly stated assertions is true, or else to show that it is false [13]. Proving processes is an endeavour that demands high-order thinking skills to construct ideas and express them logically and systematically. Therefore, to communicate the proof requires a broader and more comprehensive understanding of knowledge such as conceptual understanding, procedural knowledge, methods of proof, and reasoning abilities. Ovez and Ozdemir [14] through the literature review concluded that proving skills of prospective mathematics teachers was not at a sufficient level. The study also showed that prospective mathematics teachers had some difficulties in understanding proof and proof writing. This fact is also supported by the results of Moore's research [10] which concluded that students probably were not ready to use proof and deductive reasoning as tool for solving mathematical problems and developing mathematical knowledge. These disadvantageous situations indicate that prospective mathematics teachers are not ready to communicate their mathematical ideas through proving. Prospective teachers should be able to communicate because teacher is one of the key aspects of students successful in learning achievement [15].

The focus of this study was on the process of written mathematical communication when subject solved the mathematical proving. In describing this research, the researchers analyze the subject's written assignment result and task-based interview result. Communication activities were analyzed by reference to the written mathematical communication theory framework. Based on the results of the analysis, it is concluded that the mathematical communication activities in proving are (1) explaining what is understood, (2) describing the method used, (3) presenting the idea in the form of drawing and symbols, (4) explaining the content/meaning of a representation, and 5) conveying the argument. In general the subject could convey her ideas appropriately and coherently, but less of clearly because the description was insufficient detailed and complete.

2. Method

This research was a qualitative research. Data collection started by giving math ability test to 48 students of mathematics education program, STKIP St. Paulus-Ruteng. The results of this test were used to categorize students based on their level of mathematical ability. In the next stage, the researchers gave the proving task to the 48 students. Based on the results of the analysis, the researchers selected one of 48 students with moderate math skills as the research subject. This determination was based on the consideration that the mathematical communication profile of students with moderate math skills can at least provide an overview for the other two groups. In the next stage,

the subject of research was given Task I which contained two questions of proof, each on geometry and algebra. In addition, to describe the ability of prospective teachers in proof, the researchers also assigned the same task to other 47 students in the same class. The work results of the subject on Task I was then analyzed based on the theoretical framework of mathematical communication that had been prepared. In addition, the researchers also conducted interviews based on the work of the subject. While the work of other 47 students analyzed to get a general description of the proof ability. Furthermore, the researchers performed triangulation data by giving Task II which was similar to Task I to get valid data about the written mathematical communication profile of prospective mathematics teacher. The results of this work were then analyzed and used as the basis for interviewing the subject. The results of the analysis in the first and second stages were then compared to obtain the final data of mathematical communication profile of prospective mathematics teacher.

3. Results and discussions

The results of the mathematics test showed that of 48 students who took the test, only one student (2%) had high math skills, thirteen students (29%) had moderate math skills, and sixty-nine students (69%) had low math skills. Based on the results of the analysis, the researchers selected one of 48 students with moderate math skills as the research subject to whom the proving tasks were given.

The following description is the result of the study consisting of the general description of students' ability in mathematical proving, and the data description about the written mathematical communication profile in the proof of geometry and algebra.

3.1. An overview of student ability in mathematical proving

Task I was done by 48 students. The task consists of two questions, each measures proving skills in geometry and algebra. The two intended questions are: (1) Prove that if ABCDEF is a regular hexagonal with side length is a unit then the area of BCEF is $a^2\sqrt{3}$ unit; and (2) Prove that for every integer n , if n^2 is odd then n is odd. Based on the results of the analysis, it was found that for the first question, about geometry, only three students (6.25%) could do it correctly; three students (6.25%) could do it thoroughly but made various procedural and conceptual errors, while 42 students (87.5%) could not solve it completely. All of the students could draw the regular hexagonal correctly, but they could not find the right strategy to determine the area of BCEF. Most of them, divided the regular hexagonal into triangles and rectangle and then tried to find the length of EC by using knowledge of trigonometry and Pythagoras formulas but they failed. For the second number, about algebra, 20 students (41.7%) could solve it correctly, and the remaining 28 students (58.3 %) could do it thoroughly but made various mistakes both conceptual and procedural. In this question, most of the students chose indirect proof method using contraposition but some of them were wrong in determining it. The most common errors were algebraic manipulation and misconceptions about hypotheses and conclusions based on statements to be proved.

3.2. The written mathematical communication profile on the proving of geometry

Based on in-depth analysis, it was found out some mathematical communication activities conducted by the subject when did the proving on the geometry tasks. On the Task I, the question given was: "Prove that if ABCDEF is a regular hexagonal with side length is a unit then the area of BCEF is $a^2\sqrt{3}$ unit". The first communication activity conducted by the subject when doing this question was to explain what was understood from the problem. The subject began the proof by presenting correctly and clearly what was known and what to be proven from the question. Furthermore, the subject presented the steps of proof systematically and logically that began by presenting the idea in the form of images and symbols. The subject drew regular hexagonal correctly and then gave the names of the regular hexagonal by writing the composing letters at each vertex (see Figure 1 (a)). The subject then explained the content/meaning of the image. The subject argued that the area of BCEF is equal to the area of the rectangle. To simplify the subsequent completion, the subject drew again the area to be proved by referring to the first image that has been created (see Figure 1 (b)). The subject could draw

this idea correctly but in less detail so that it was rather difficult to understand. The mathematical symbols used were also less consistent. And then, based on the new picture, the subject constructed and presented argument to show that the area of BCEF is $a^2\sqrt{3}$ unit but the subject could not convey the argument correctly and logically. The argument presented was not clear because it was not well-detailed. The subject said that the length of $x = \sqrt{2}a$ but she did not give an explanation of why it was so.

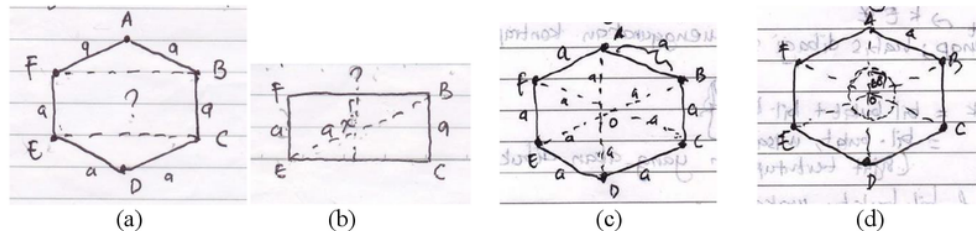


Figure 1: Student's answer on the proof of geometry

Furthermore on the Task II, the question given was: "Prove that the regular hexagonal area with the side length is a is $\frac{3}{2}a^2\sqrt{3}$ unit". The subject began the proof by explaining what she understood, related to the known element and the conclusion to be proven. The subject could explain the idea correctly, systematically and completely. Then the subject presented systematically the steps of proof that began by presenting the idea in the form of pictures and symbols (see Figure 1 (c)) and followed by an explanation regarding to the content/meaning of the drawing. The explanation given could be well understood because it was quite simple. To facilitate the subsequent completion, the subject presented again the idea in the form of drawing of the regular hexagonal, including a circle in it (see Figure 1(d)), and followed by describing the contents of the drawing. The subject explained her idea systematically and logically by using simple language so that it could be well understood. Based on the new drawing the subject conveyed argument to show that the area of a regular hexagonal with side length is a is $\frac{3}{2}a^2\sqrt{3}$ unit. The subject conveyed the argument accurately but not systematically.

Based on the description above, it appears that the sequence of activities of the written mathematical communication on the proving of geometry is: (1) explaining what is understood, (2) presenting the idea in the form of drawing and symbols, (3) explaining the content/meaning of a representation, (4) presenting the idea in the form of drawing and symbols, and then closed by (5) conveying an argument. The subject explained what is understood correctly and then presented the idea in the form of drawing and symbols in detail and complete. The subject can explain the content/meaning of a representation accurately and clearly, but the subject cannot convey the argument systematically. The mathematical symbols used are also less consistent.

3.3. The written mathematical communication profile on the proving of algebra

The results of the analysis showed that there were some mathematical communication activities conducted by the subject when doing the proving tasks on algebra. In task I, the question given was: "Prove that for every integer n , if n^2 is odd then n is odd". The first mathematical communication activity raised was explaining what was understood namely the elements that were known and to be proven. The subject could explain what is understood correctly and completely. According to the subject, the known elements are n is integer and n^2 is odd, and the element to be proved is n is odd. Furthermore, the subject explained the method to be used namely indirect proof by using contraposition. This second step was not done by the subject on the proof of geometry. The subject could not explain this idea in detail and complete. The ideas presented were also unclear because they were not well ordered and were not accompanied by adequate explanations. Based on the prescribed

method, the subject presented the proving steps systematically and logically, beginning with putting forward the argument, and continued by explaining the symbolic representation contained in the argument. The subject described these ideas correctly but not in detail and incomplete. The subject ended the proof by conveying argument systematically and logically and using simple and understandable language. She said: "So, it is proven that if n is even then n^2 is even, so it is true that if n^2 is odd then n is odd". The subject could show conclusively that the statement was true.

Further, in the Task II, the question given was: "Prove that for every integer n , if n^2 is even then n is even". As in the previous task, the subject began the proving by explaining the elements that she understood from the problem. Those were the known things and the things to be proved. The subject explained the idea in detail and complete, starting from what was known and followed by what to be proved. According to the subject, the known elements are n is integer and n^2 is even, and the element to be proved is n is even. Additionally, the subject suggested the method to be used namely proof by contraposition, which was preceded and ended with a brief and clear explanation about atomic propositions. The subject said that the proposition: $p \rightarrow q$ was equivalent to its contraposition: $\sim q \rightarrow \sim p$. By referring to the contraposition, the subject re-explained the elements that are known and which will be proved. According to the subject, the known element is n is odd, and the element to be proved is n^2 is odd. The subjects could explain the ideas correctly, detailed, and complete. Based on this chosen method, the subject presented the proving steps. The subjects could present these steps in a systematic way, accompanied by explanations for each step taken. The subject also explained the meaning of any symbolic representations used in the argument using simple and understandable language. The subject ended the proving by arguing that the given statement was true. She said: "Proven, if n is odd then n^2 is odd, with $n \in \mathbb{Z}$, so it is true that if n^2 is even then n is even".

Based on the description above, it appears that the sequence of activities of the written mathematical communication on the proving of algebra is: (1) describing what is understood, (2) describing the method used, (3) conveying the arguments, (4) explaining the content/meaning of a symbolic representation, and then closed by (5) conveying the argument. Generally, the subject could convey all of the ideas appropriately and coherently, but less of clearly because the description was insufficient detailed and incomplete.

3.4. The written mathematical communication profile on the proving of algebra

The results description above showed that, there is quite difference in the pattern of mathematical communication on the two questions given, both in Task I and Task II. To prove the truth of statements in the field of geometry, the subject tends to use images as mental representations. These images are used to reduce the concept abstraction, and make it more concrete so that all the important elements involved in reaching the solution will become apparent. The images are helpful to the subject in explaining her ideas in detail and completely, logically and systematically. Moreover, these images can help the reader to navigate the subject's thinking flowing well. An explanation that directly refers to a concrete image is more easily understood so that the truth of the proposed ideas can be easily accepted. Furthermore, when working on the proof of geometry, the subject do not convey the method or strategy used, but directly use the known facts to show the truth of the statement to be proved. It means that the subject uses direct proof method. While on the proof of algebra, the subject explicitly explains the method that will be used that is indirect proof with contraposition. The problem given on the proving of algebra cannot be solved by direct proof. If using direct proof, the subject will face difficulty in performing algebraic manipulations to show conclusively that the statement is true. This condition forces the subject to search for other suitable methods. Therefore, the subject always begins her proof by altering the initial statement into another equivalent form called the contraposition. By using contraposition, the subject can easily show conclusively that the statement is true.

5 Conclusions

Based on the results of this study, it can be concluded that in the proof of geometry, the subject explains what is understood, presents the idea in the form of drawing and symbols, and explains the

content/meaning of a representation accurately and clearly, but the subject cannot convey the argument systematically and logically. Whereas in the proof of algebra, the subject describes what is understood, explains the method used, and describes the content/meaning of a symbolic representation accurately, systematically, logically, but an argument presented is not clear because it is insufficient detailed and incomplete.

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