CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

Female Student Mathematical Communication Ability in the Proving Process: a Review Based on Math Anxiety

Habilidade de comunicação matemática da aluna no processo de comprovação: uma revisão baseada na ansiedade matemática

Kristianus Viktor **Pantaleon**[*]

ORCID iD 0000-0002-1543-7251

Dwi **Juniati**[**]

ORCID iD 0000-0002-5352-3708

Agung **Lukito**[***]

ORCID iD 0000-0003-1277-5834

Abstract

This qualitative research aimed to explore the mathematical communication profile of prospective mathematics teachers in-depth, while also examining their levels of math anxiety. Mathematical communication involves delivering mathematical ideas and understandings through written and verbal means, using mathematical language in the form of symbols, signs, terms, formulas, images, and words. The study's subjects were two female fifth-semester students from mathematics education study programs, one with High Math Anxiety (HMA) and one with Low Math Anxiety (LMA). Data were collected through various methods, including tests, assignments, questionnaires, and interviews. The findings of the study indicated that the HMA student accurately conveyed ideas in writing, but was less systematic and logical, whereas the LMA student expressed ideas correctly, systematically, and logically, but sometimes made accidental technical errors. Additionally, the HMA student did not pay much attention to the regularity and accuracy of her thoughts during oral communication. In contrast, the LMA student demonstrated a strong interest in learning, and was able to convey her ideas in a systematic, logical, detailed, complete, and correct manner.

Keywords: Mathematical communication. Math anxiety. Accuracy. Coherence. Clarity.

Resumo

Esta pesquisa qualitativa teve como objetivo explorar o perfil de comunicação matemática de futuros professores de Matemática em profundidade, ao mesmo tempo em que examina seus níveis de ansiedade matemática. A comunicação matemática envolve a entrega de ideias e entendimentos matemáticos por meios verbais e não-verbais, usando linguagem matemática na forma de símbolos, sinais, termos, fórmulas, imagens e palavras. Os sujeitos do estudo foram dois alunos do quinto semestre de programas de estudo de Educação Matemática, um

[*] Doctor in mathematics education from Universitas Negeri Surabaya (UNESA). Lecturer and researcher from Universitas Katolik Indonesia Santu Paulus (UNIKA) Ruteng, Nusa Tenggara Timur, Indonesia. E-mail: christianvictor1979@gmail.com.

[**] Professor in mathematics education from Univ. D Aix Marseille I France. Lecturer and researcher from Universitas Negeri Surabaya (UNESA), Jawa Timur, Indonesia. E-mail: dwijuniati@unesa.ac.id.

[***] Doctor in mathematics education from Delft University of Technology (TU Delft), Belanda. Lecturer and researcher from Universitas Negeri Surabaya (UNESA), Jawa Timur, Indonesia. city, state and country. E-mail: agunglukito@unesa.ac.id.

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

com alta ansiedade matemática (HMA) e outro com baixa ansiedade matemática (LMA). Os dados foram coletados por meio de vários métodos, incluindo testes, tarefas, questionários e entrevistas. Os resultados do estudo indicaram que o aluno do HMA transmitiu com precisão as ideias por escrito, mas foi menos sistemático e lógico, enquanto o aluno do LMA expressou as ideias de maneira correta, sistemática e lógica, mas, em alguns momentos, cometeu erros técnicos acidentais. Além disso, o aluno do HMA não prestou muita atenção à regularidade e precisão de seus pensamentos durante a comunicação oral. Em contrapartida, o aluno da LMA demonstrou forte interesse em aprender e foi capaz de transmitir suas ideias de maneira sistemática, lógica, detalhada, completa e correta.

Palavras-chave: Comunicação Matemática. Ansiedade Matemática. Precisão. Coerência. Clareza.

1 Background

The National Council of Teachers of Mathematics (NCTM, 2000) recognizes that communication plays a crucial role in both mathematics and mathematics education. Communication helps students to formalize mathematical concepts and strategies. Communication skills are essential to student success in approaching and solving mathematical exploration and investigations (GREENES; SCHULMAN, 1996). Teachers could promote student interest, involvement, and interaction through communication while concentrating on deep conceptual understanding (POURDAVOOD; WACHIRA, 2015; YANG *et al*., 2016). Besides, through communication, students learn to communicate using mathematical language (NCTM, 2000). Unfortunately, the PIZA test results in mathematics and science showed that in 24 countries more than 50% of students scored below the level of proficiency (OECD, 2019). The data confirm that basic mathematical abilities, such as problem-solving, communication, connections, reasoning and proof, and representations (NCTM, 2000), are still common issues that require immediate resolution through scientific studies. Therefore, as one of the basic mathematics abilities, research on mathematical communication still needs to be carried out, primarily related to the various psychological factors that influence it, such as math anxiety.

There have been many previous research studies on mathematical communication, but they have not covered all aspects that, theoretically, are related to mathematical communication. Recently, studies on mathematical communication tend to conduct experiments to see the effect of implementing a learning method on mathematical communication skills (QOHAR; SUMARMO, 2013; SUNDAYANA *et al*., 2017; TRISNAWATI; PRATIWI; WAZIANA, 2018; SIREGAR *et al*., 2018).

These studies showed that the experimental classes taught by innovative learning methods have higher communication skills than other classes. Many psychological factors, such as anxiety, curiosity, interests, and motivation, are not considered. Several other studies have tried to develop methods or strategies to improve the students' mathematical communication

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

skills (CLARK *et al*., 2005; SARI, 2017; ZAKIRI; PUJIASTUTI; ASIH, 2018; TRIANA; ZUBAINUR, BAHRUN, 2019).

These studies are related to cognitive aspects, such as developing the teacher handbook, student book, student worksheet, and mathematical skill test. Psychological aspects are less or even not considered in these studies. Likely, other studies have also analyzed mathematical communication difficulties (BRASLASU, 2015). However, the analysis was also limited to the cognitive aspects and had not touched the psychological aspects. There is also a study that tries to analyze the cognitive and emotional aspects of mathematical communication among pre-service teacher students (INPRASITHA; PATTANAJAK; INPRASITHA, 2012). However, the emotional aspects studied are general and have not touched on math anxiety.

Following up on the gaps in previous studies above, in the present study, the researchers examined mathematical communication skills, especially in solving proof problems, considering the level of math anxiety of each subject studied. Studies of the effects of math anxiety have not shown consistent results. On the one hand, research results showed that math anxiety is a negative thing. Math anxiety disrupts cognitive processing by compromising ongoing activity in working memory (ASHCRAFT; KIRK, 2001), harms mathematics performance (NAMKUNG; PENG; LIN, 2019; OZCAN; GUMUS, 2019), metacognitive knowledge (HOORFAR; TALEB, 2015), and problem-solving abilities. However, on the other hand, math anxiety is considered a positive thing. Math anxiety can be an impetus for students to study mathematics in earnest. In this case, math anxiety can be seen as progressive thinking and not regressive thinking (BELBASE, 2013). These facts prompted the researchers to study math anxiety in-depth to see its actual contribution to mathematical communication.

The researchers selected female students in the current research with two important considerations. First, based on the research results, female students have a stronger adverse affective reaction than male students (WIGFIELD; MEECE, 1988). Another study claimed that female teachers' math anxiety affects the learning achievement of female students but does not affect male students (BEILOCK *et al*., 2010). This concept means that the affective reaction to a negative stimulus (for example, teacher math anxiety) is more robust in women. Research also showed that female math anxiety is higher than male math anxiety in primary and secondary schools (HILL *et al*., 2016).

Meanwhile, another study showed that math anxiety was significantly correlated with math performance (MIER; SCHLEEPEN; BERG, 2019). Therefore, by selecting female students, the researchers hoped to obtain more in-depth data on the impact of math anxiety on mathematical communication. Second, the study results also showed that female students'

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

mathematical communication skills are higher than male students' (HAYATI; SUTIARSO; DAHLAN, 2019). The researchers aim to avoid gender bias in analyzing mathematical communication skills by selecting only female students.

Based on the description above, this current study intends to describe prospective mathematics teachers' mathematical communication profiles in solving proof tasks viewed from math anxiety level. The feeling of anxiety reflects a psychological condition that can significantly influence – (being both beneficial and detrimental) – one's performance in many interaction contexts. This study would deeply examine how the feeling of anxiety can affect one's performance in communicating ideas determined by three indicators comprising (NCTM, 2000): accuracy (suitability of ideas with applicable standards or facts on the questions), coherence (regularity of ideas conveyed), and clarity (completeness, detail, and convenience in understanding the ideas conveyed).

2 Theoretical Review

2.1 Mathematical Communication

Mathematical communication refers to the process of sharing and clarifying mathematical ideas and understanding through various forms of communication, such as verbal, visual, and written means. This includes the use of numbers, symbols, images, graphics, diagrams, and words, as recognized by the National Council of Teachers of Mathematics (NCTM) in 2000 and the Ministry of Education (2005).

Mathematical communication is also defined as expressing mathematical thinking by using mathematical language precisely and concisely (YANG *et al*., 2016). It can be concluded that mathematical communication delivers mathematical ideas or understandings both written and verbally by using mathematical language in symbols, signs, terms, formulas, images, and words.

Mathematical communication appears in various mathematical activities. In general, there are four mathematical communication activities, namely (1) organizing and consolidating mathematical thinking through communication, (2) communicating mathematical thinking coherently and clearly to friends and teachers, (3) analyzing and evaluating other people's mathematical thinking, and (4) using the language of mathematics to express mathematical ideas appropriately (NCTM, 2000). More specifically, mathematical communication appears in activities: (1) expressing ideas through speech, writing, demonstration, and visualizing them in

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

different ways, (2) understanding, interpreting, and evaluating views expressed verbally, in writing, or visual form, (3) constructing, interpreting, and linking various representations of ideas and relations, (4) observing, constructing conjectures, asking questions, collecting, and evaluating information, and (5) producing and expressing arguments convincingly (GREENES; SCHULMAN, 1996).

Mathematical communication in the present study is divided into two types, namely written mathematical communication and oral mathematical communication. Written mathematical communication delivers ideas or understanding of mathematics by writing it on the answer sheet. Simultaneously, verbal mathematical communication is the delivery of ideas or knowledge of mathematics by explaining it verbally in front of a group of students while (if necessary) writing it on the board.

Mathematical communication has its uniqueness when compared to communication in general. Mathematical communication is universal, precise, concise, and logical (KLOCHKOVA; KOMOCHKINA; MUSTAFINA, 2016). Mathematical communication characteristics are *purity,* accuracy, and concision (IONESCU, 2015). Purity means using only the words admitted in the vocabulary of the literary language. *Accuracy* aims to use those words and phrases necessary for understanding communication. At the same time, *concision* means seeking an expression focused on the communicated subject without additional and void divagations. Mathematical ideas should be conveyed precisely, coherently, and clearly (NCTM, 2000).

The characteristics of mathematical communication study are accuracy, coherence, and clarity. Accuracy is the suitability of mathematical language, terms, symbols, signs, or formulas with standard forms in mathematics. The accuracy also refers to the suitability of the method used. Moreover, accuracy requires the compatibility between the information conveyed and the facts contained in the problem or according to the standards that are applied in mathematics (NCTM, 2000). Coherence integrates arguments or explanations obtained by logically and systematically organizing statements. Besides, coherence also refers to the consistency of using symbols and mathematical terms (LEE, 2012). Whereas clarity is related to the detail and completeness of the information and the ease of understanding the language used (LEE, 2012).

2.2 Math Anxiety

Anxiety is an unpleasant emotional state or condition that includes apprehension, tension, worry, and physiological arousal (SPIELBERGER; REHEISER, 2009). It is marked

cc BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

by foreboding and somatic signs of tension, such as racing heart, sweating, and often, difficulty breathing (SCHWARTZ, 2000). There are two general types of anxiety: state and trait (MILLER; BICHSEL, 2004). State anxiety is a transitory emotional state consisting of tension, apprehension, nervousness, and worry that arise in certain situations perceived as a threat (SPIELBERGER; REHEISER, 2009). Furthermore, trait anxiety is the stable tendency to feel anxious across many situations. Trait anxiety refers to the relatively stable individual differences in anxiety-proneness. This is reflected in the frequency of anxiety states manifested in the past and the likelihood of experiencing feelings of state anxiety in the future (SPIELBERGER; REHEISER 2009, p. 276). Trait anxiety is not immediately visible in individual behavior but can be seen from individual states' frequency.

Math anxiety is a state of anxiety or worry when attending classes or dealing with mathematical problems (MUTAWAH, 2005). It is a debilitating adverse emotional reaction towards mathematics (HILL *et al*., 2016). The effect is in feeling helpless or unable to overcome various mathematical challenges. It is a multidimensional psychological construct involving complex factors, such as feeling depressed, inadequate, and anxious, that interfere with manipulating numbers and solving mathematical problems (KVEDERE, 2014). Math anxiety is also an anxious state in responding to mathematics considered a threat (BELBASE, 2013). This anxiety arises from negative thoughts and feelings towards mathematics that trigger unnatural behavior or response, such as uncomfortable, nervous, or afraid (YENILMEZ; GIRGINER; UZUN, 2007).

Math anxiety affects three main aspects of personality with easily detectable symptoms. First, math anxiety affects cognitive aspects, namely mathematical thinking (KARGAR; TARMIZI; BAYAT, 2010; RECTOR *et al*., 2008). The symptoms are losing control, thinking of being stupid, and being afraid to be embarrassed. Second, math anxiety affects the physical aspect, namely how the body feels and works (RECTOR *et al*., 2008). Symptoms that can be seen include heart palpitations, sweating, shaking, shortness of breath, chest pain, dizziness, nausea, and muscle tension. In addition, it also affects a person's attitude, namely how to act (RECTOR *et al*., 2008). Symptoms can include avoiding situations or activities that are frightening. In the end, math anxiety will affect math performance (KARGAR; TARMIZI; BAYAT, 2010).

In this study, math anxiety is a relatively stable anxious state when responding to matters related to mathematics (trait anxiety). In this respect, math anxiety was determined based on the results of the math anxiety questionnaire. The math anxiety levels examined in this study were categorized as high math anxiety and low math anxiety. In other words, the study aimed

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

to investigate the levels of math anxiety experienced by participants, distinguishing between those who exhibited high levels of math anxiety and those who displayed low levels of math anxiety.

3 Method

3.1 Research Design

This qualitative research begins by determining the research subject. The subjects were students of the fifth semester of the mathematics education study program, Universitas Katolik Indonesia Santu Paulus Ruteng. Selected subjects were inquired to sign a consent form to participate in this study. The subjects were assigned to work on the answer sheet to support their written mathematical communication competence. The interview was also conducted to collect the data to understand the subjects' written mathematical communication data.

The selected subjects were also assigned to have an oral presentation before grade VIII in the science department. The researchers recorded every part of the subject's oral presentation and took essential notes. The results were transcribed into the written ones and used as the guidelines in the interview. Furthermore, the researchers also took notes of the subjects' ideas written on the board during their oral presentations. To ensure data reliability, the researchers tested the data credibility using the time triangulation technique. Ultimately, the researchers compared the data obtained from different times (Table 1).

Table 1 – Subject determination rules

Subjects	**Math anxiety score** (Score range: 30 – 120)	**Mathematics ability score** (Score range: 0 – 100)
HMA	91 – 120	70 – 100
LMA	30 – 60	70 – 100

Source: Prepared by the author (2023).

3.2 Research Subject

Participants in the study were selected using a purposive sampling technique. Participants had to be communicative and had high mathematical skills (based on the results of the mathematics ability test). Selecting the subject began by giving a math ability test to 48 students of the mathematics education study program, Universitas Katolik Indonesia Santu Paulus Ruteng. This test attracted students with high math skills (the score is > 70). This category was selected to avoid difficulties of the proving task given; thus, more reliable and

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

accurate data about the subjects' mathematical communication competence could be identified. The math anxiety test was then given to measure their level of math anxiety. Through this kind of test, two students with different levels of math anxiety, HMA (the score obtained is > 91) and LMA (the score obtained is < 60), were determined as the subjects. The rules for determining the subject can be seen in Table 1.

3.3 Research Instrument

This data collection techniques were tests, assignments, questionnaires, and interviews. To obtain accurate data, the researchers used three supporting instruments, namely the Math Anxiety Questionnaire (MAQ), Mathematical Ability Test (MAT), and Mathematical Proving Task (MPT). Moreover, as additional data, the researchers also prepared a response questionnaire to obtain student responses to the subject's ability to convey mathematical ideas orally. The math ability test was used to determine the mathematical ability. In this study, both subjects should have relatively the same mathematical skills. The math ability test in this study was made in an essay test consisting of ten items. The ten questions were valid, with the lowest product-moment correlation coefficient being 0.4.

Meanwhile, the reliability coefficient of the instrument is 0.85. The math anxiety test is used to determine the subject's level of math anxiety. The two selected subjects must have different anxiety levels, namely high and low. The math anxiety test was composed of a questionnaire that consisted of thirty items. The questionnaire used in this study provided alternatives of answers comprising: always, often, rarely, and never. The test is adapted from tests that have been developed by other researchers (MUTAWAH, 2005), having a 0.86 level of reliability coefficient.

Furthermore, the mathematical proving task consisted of two questions related to geometry and algebra. The two questions are (1) prove that if $ABCDEF$ is a regular hexagon with side length is a unit, then the area of $BCEF$ is $a^2\sqrt{3}$ units squared, and (2) prove that for every integer n, if n^2 is odd, then n is odd. The researchers prepared two other questions equivalent to the two previous questions for triangulation purposes. The two questions are (1) prove that the area of a regular hexagon with side length a unit is $3a^2\sqrt{3}/2$ unit squared, and (2) prove that for every integer n, if n^2 is even, then n is even. The two mathematicians validated these four questions. The researchers also conducted interviews to obtain more accurate data. The results of the two subjects' work and the results of observations were used to conduct

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

interviews.

Researchers chose geometry and algebra because, in Indonesia, mathematics material at the secondary school level can be divided into two categories: geometry and algebra. In geometry, the researchers arrange problems that can be solved using pictures. While in the algebraic material, the researchers compiled problems whose solutions do not use pictures. This way, richer data would be obtained about the mathematical communication of the subject, especially in the context of using symbols, signs, terms, and images.

3.4 Data Analysis

Data analysis was carried out in three stages: data reduction, presentation, and conclusion. The researchers analyzed by referring to the indicators of mathematical communication presented in Frame 1. The researchers used time triangulation to ensure data credibility. Time triangulation was done by giving MPT twice, using different questions, but measuring the same indicators.

4 Research Result

The research findings are presented in this section. The researchers begin the presentation by giving a brief overview of the two research subjects based on the math ability test results, math anxiety test, and interview results. The two subjects' mathematical communication profiles referring to the indicators of mathematical communication skills are described, as presented in Frame 1.

Indicator	Ideal Condition
1. Describe the elements known and those that can be proven.	The elements are mentioned precisely (according to the question) and clearly (detailed and complete).
2. Using symbols, signs, terms, or mathematical formulas to convey mathematical ideas.	All symbols or terms are used correctly and consistently
3. Describe relevant things, such as concepts, facts, or methods related to the problem-solving process (if necessary).	Relevant things are explained precisely, coherently, and clearly.
4. Present completion steps.	The completion steps are presented coherently and clearly, and the results are also correct.
5. Justify the reasoning process by presenting supporting reasons or arguments.	The reasons for justification are stated precisely, coherently, and clearly.
6. Explain ideas by visualizing them (if they are related to images).	The resulting images follows the information on the question and are equipped with good symbols/signs so that it is easy to understand.
7. Present conclusion	The presented conclusion is correct and easy to understand.

Frame 1 - Indicators of mathematical communication

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

Source: Prepared by the author (2023).

4.1 Brief Overview of Research Subjects

The results of the math ability test showed that HMA and LMA have relatively the same abilities. HMA and LMA obtained scores of 74.60 and 76.19, respectively. The difference in scores between them is relatively small, then it is assumed that this difference does not affect mathematical communication skills. On the other hand, based on the math anxiety test results, HMA and LMA obtained 95 and 45, respectively. The difference in these scores is considered quite large, so that, it is assumed, affects their mathematical communication skills.

The participants selected were female students of relatively the same age. HMA was 23 years old, while LMA was 24 years old. Based on the interview results, both are students of the 5th semester of the mathematics education study program. HMA is the student from a village, while LMA is the student who comes from the city. HMA is a quiet student and does not ask many questions in class. Meanwhile, LMA is a quite active student in class, especially in answering questions. However, both have the same mathematical ability, which can be seen based on the math ability test results and the average scores each semester.

4.2 HMA's Written Mathematical Communication Ability

The evaluation results showed that in Problem 1, not all mathematical communication activities were carried out correctly. The HMA described the known elements and elements to be proven in detail, complete, and correct. The HMA also presented the completion steps systematically and logically, and the results were accurate. She also used pictures to explain ideas. The images matched the questions and were equipped with adequate information to understand. She also formulated a conclusion in simple and easy-to-understand language. The conclusion made also met the purpose of proof. She used various symbols, signs, formulas, and mathematical terms. However, not all symbols were used correctly. Besides, she also explained methods or ways that support the problem-solving process. However, she was less systematic in describing these ideas. She justified her reasoning process by proposing supporting reasons or arguments. However, most reasons or arguments were not stated correctly and systematically.

Likewise, in Problem 2. In this question, the HMA presented the known elements and element to be proven in detail, complete, and correctly, but she was not systematic and logical in showing further completion steps. Relevant things that support problem-solving were also

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

not explained systematically. The argumentation given for justifying the reasoning process were also not systematically stated. On the other hand, she could use mathematical symbols, terms, and formulas correctly and consistently. The conclusion presented was precise, systematic, and easy to understand. The researcher interviewed the participant to support written data and find the relationship between mathematical communication and math anxiety. The participant was quite careful in writing down her ideas from the interview results. This way was done by rechecking her writing repeatedly until she was sure there was no bad writing. In summary, HMA's written mathematical communication ability is presented in Frame 2.

Indicator	Subject's ability
1. Describe the elements known and those that can be proven.	clear, accurate, coherent
2. Using symbols, signs, terms, or mathematical formulas to convey mathematical ideas.	clear, less accurate, less coherent
3. Describe relevant things, such as concepts, facts, or methods related to the problem-solving process (if necessary).	clear, accurate, less coherent
4. Present completion steps.	clear, accurate, less coherent
5. Justify the reasoning process by presenting supporting reasons or arguments.	less clear, less accurate, less coherent
6. Explain ideas by visualizing them (if they are related to images).	clear, accurate, coherent
7. Present conclusion	clear, accurate, coherent

Frame 2 - HMA’s written mathematical communication ability
Source: Prepared by the author (2023).

4.3 HMA’s Oral Mathematical Communication Profile

The HMA described the known elements and proven elements in the two questions in detail, completely, and correctly based on the analysis results. She also used mathematical symbols and terms correctly to be well-understood. Besides, she could also present a conclusion with her language precisely, logically, systematically, and clearly.

Indicator	Subject's ability
1. Describe the elements known and those that can be proven.	clear, accurate, coherent
2. Using symbols, signs, terms, or mathematical formulas to convey mathematical ideas.	clear, accurate, coherent
3. Describe relevant things, such as concepts, facts, or methods related to the problem-solving process (if necessary).	clear, accurate, less coherent
4. Present completion steps.	clear, accurate, less coherent
5. Justify the reasoning process by presenting supporting reasons or arguments.	clear, accurate, less coherent
6. Explain ideas by visualizing them (if they are related to images).	less clear, less accurate, less coherent
7. Present conclusion	clear, accurate, coherent

Frame 3 - HMA’s oral mathematical communication ability
Source: Prepared by the author (2023).

Furthermore, she explained things relevant to solving the problem, such as the strategies and related concepts to support the settlement process. The concepts were explained correctly,

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

systematically, and logically. However, not all procedures used were explained systematically. The settlement steps presented were not all systematic. In solving Problem 1, the HMA showed the solution steps systematically, logically, and appropriately. However, in Problem 2, the completion steps presented were less systematic. Besides, she also raised reasons or arguments to justify her reasoning process. However, not all reasons or arguments were stated logically and systematically. In Problem 1, she presented the reasons correctly, systematically, and logically to be easy to understand. However, in Problem 2, the arguments raised were not systematic enough to be challenging to understand. Furthermore, she also presented her ideas using images. The resulting image followed the information on the question; however, the image did not follow the explanation and was not equipped with symbols or good signs. In summary, the HMA's oral mathematical communication ability is presented in Frame 3.

Based on the presented results, we interviewed the HMA to detect math anxiety's influence on her mathematical communication profile. The interview results show that the HMA wants to finish her assignments at once as she wants to feel relieved immediately. She felt uncomfortable before completing all the tasks given.

4.4 LMA's Written Mathematical Communication Profile

Based on the analysis, it was found that in Problem 1, not all mathematical communication activities were carried out correctly. The LMA was not very careful in writing down known elements. The complete steps in Problem 1 were also incomplete, even though the result obtained was correct. On the other hand, in Problem 1, the LMA could correctly use symbols, signs, terms, and formulas. Besides words, she also uses a picture to express her ideas. The image is correct, systematic, and easy to understand. She also justified her reasoning by presenting reasons or arguments systematically and logically. The conclusion given was simple, precise, and easy to understand.

In Problem 2, the LMA could convey all of her ideas well. She explained the known elements and elements that would be proven in detail, complete, and correct. Symbols, signs, terms, and mathematical formulas were also used correctly and consistently. She also explained the method and justified her reasoning process by presenting reasons systematically and logically. Besides, she also presented completion steps and formulated conclusions systematically and logically. In summary, the LMA's written mathematical communication ability is presented in Frame 4.

Indicator	Subject's ability

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

1. Describe the elements known and those that can be proven.	less clear, accurate, less coherent
2. Using symbols, signs, terms, or mathematical formulas to convey mathematical ideas.	clear, accurate, coherent
3. Describe relevant things, such as concepts, facts, or methods related to the problem-solving process (if necessary).	clear, accurate, coherent
4. Present completion steps.	clear, accurate, coherent
5. Justify the reasoning process by presenting supporting reasons or arguments.	clear, accurate, coherent
6. Explain ideas by visualizing them (if they are related to images).	clear, accurate, coherent
7. Present conclusion	clear, accurate, coherent

Frame 4 - LMA's written mathematical communication ability
Source: Prepared by the author (2023).

Based on her writing results, the LMA was not careful in writing down her ideas. Therefore, to find out the cause, we interviewed the subject. The interview results showed that the LMA did not re-examine her work after completing it. She could not find out the small mistakes that occurred in her test. On the other hand, the LMA was quite confident in completing the task given. She was sure that her work was correct, so there was no need to recheck it.

4.5 LMA's Oral Mathematical Communication Profile

The analysis showed that almost all oral mathematical communication activities were correctly done. The LMA explained the known elements and proven elements in detail, complete, and correctly in both questions. Mathematical symbols, signs, terms, and formulas were used correctly and consistently. The completion steps were presented systematically and logically, and the results were also correct. She justified her reasoning process by presenting reasons or arguments systematically and logically. She also used pictures to explain her ideas. Images were equipped with appropriate symbols and signs. She also conveyed conclusions systematically, logically, and correctly. However, she did not carefully write the conclusion on the board. The conclusion was not in line with what was said. Besides, she was not thorough in explaining illustrations to convince students that Problem 2 cannot be done by directly proving. In summary, LMA's oral mathematical communication ability is presented in Frame 5.

Indicator	Subject's ability
1. Describe the elements known and those that can be proven.	clear, accurate, coherent
2. Using symbols, signs, terms, or mathematical formulas to convey mathematical ideas.	clear, accurate, coherent
3. Describe relevant things, such as concepts, facts, or methods related to the problem-solving process (if necessary).	clear, accurate, coherent
4. Present completion steps.	clear, accurate, coherent
5. Justify the reasoning process by presenting supporting reasons or arguments.	clear, accurate, coherent

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

6. Explain ideas by visualizing them (if they are related to images).	clear, accurate, coherent
7. Present conclusion	clear, accurate, coherent

Frame 5 - LMA's oral mathematical communication ability
Source: Prepared by the author (2023).

Based on the learning video analysis results, the LMA spent considerable time explaining the two questions. Besides, she also made minor technical errors. For this reason, the researchers interviewed the subject to clarify these matters. Based on the interview results, the LMA was pleased and encouraged to explain her ideas to students. However, not all of them were essential or directly related to the explained material. On the other hand, she seemed inadvertent in writing and explaining her ideas and often made unintentional technical mistakes (not substantial mistakes).

5 Discussion

This study indicated that math anxiety influences both female students' mathematical communication skills. In written mathematical communication, the participant who has a high level of math anxiety tends to write down her ideas more carefully. Some researchers found that "heightened automatic biases in anxiety may contribute to a cycle of hypervigilance" (WILLIAMS *et al*., 2007, p. 1595). In this study, the HMA checked her writing to ensure nothing was wrong. She tends to be less systematic in conveying her ideas, even though the ideas are true. During oral mathematical communication with students, she tends to rush through the task in order to alleviate feelings of depression and anxiety as quickly as possible. Therefore, she did not pay much attention to the regularity of the ideas conveyed orally. The most important thing is to complete the task given immediately. The tendency to avoid or wanting to be free from stressful situations is one indicator of math anxiety (RECTOR *et al.*, 2008).

Unlike the previous subject, the LMA tends to be less careful in writing down her ideas. The LMA is always sure that the writing is correct, so she did not recheck after completing it. As a result, she could not detect any minor accidental errors. Whereas in oral mathematical communication, she enjoyed learning. Many things she explained during the learning process, ranging from things that support the process of solving the problem to the general things related to the explained material. She also made jokes often, making the classroom atmosphere becomes interactive, and students are more enthusiastic in listening to the explanation. Furthermore, the time spent by the LMA to explain her ideas was also more (twice) than the time taken by the HMA. The LMA appears to be less economical in explaining her ideas

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

because what was explained were things directly related to problem-solving and were not directly related to problem-solving.

When completing proof problems, the researchers found that the oral mathematical communication activities were more detailed and numerous than written mathematical communication activities. In oral presentations, both subjects dealt with students, so they had to adjust to them. In other words, the length of the proving process also depends on the listener (LEE, 2012). We may not need a more detailed explanation when writing for ourselves because we understand why one step can follow another. However, when dealing with other people who have lower ability levels than us, we have to explain it in more detail so that our readers or listeners can understand it well.

Furthermore, this study indicated that the two participants could not perform the tasks efficiently, either verbally or in writing. The participant with high anxiety levels could not work well because she was overwhelmed by anxiety (NAMKUNG; PENG; LIN, 2019; OZCAN; GUMUS, 2019). Meanwhile, the participant with low anxiety levels should have a good performance. The researchers assume that the absence of anxiety (low levels of anxiety) makes students less careful in doing assignments and tending to take them lightly and not preparing themselves better. Therefore, the researchers recommend that future studies should involve participants with normal anxiety levels. “A certain amount of anxiety is normal and necessary; it can lead you to act on your concerns and protect you from harm. In some situations, anxiety can even be essential to your survival” (RECTOR *et al*., 2008, p. 4). Normal anxiety will motivate students to prepare themselves better (BELBASE, 2013). This study included only two participants with high and low anxiety levels but did not include normal level ones. The researchers also only included female students and did not include male students. It would be better to include both of them to compare the results.

6 Conclusions

A female’s ability to communicate mathematically while solving proof problems is also influenced by the level of math anxiety she experiences. In other words, the degree to which a female experiences math anxiety can impact her mathematical communication profile when attempting to solve proof problems. The subject with high math anxiety levels is less systematic than the subject with low math anxiety levels, even though the idea is correct. However, the subject tends to be more careful in expressing her ideas. While the subject with low levels of math anxiety, not thorough or cautious in conveying her thoughts, she often makes accidental

cc BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

technical mistakes. However, a subject with low levels of math anxiety is more systematic in conveying ideas. Yet, both subjects are incomplete in general expressing their ideas in terms of written mathematical communication.

References

ASHCRAFT, M. H.; KIRK, E. P. The relationship among working memory, math anxiety, and performance. **Journal of Experimental Psychology: General,** Washington, *130*, 224-237, 2001.

BEILOCK, S. L.; GUNDERSON, E. A.; RAMIREZ, G.; LEVINE, S. C. Female teachers' math anxiety affects girls'math achievement. **Psychological and Cognitive Sciences**, Chicago, *107*, 1860-1863, 2010.

BELBASE, S. Images, anxieties, and attitudes toward mathematics. **International Journal of Education in Mathematics, Science and Technology,** Wyoming, *1*, 230-237, 2013.

BRASLASU, M. Aspects of didactic communication in primary School. **Procedia -** Social and Behavioral Sciences, Luxembourg, *180*, 497-501, 2015.

CLARK, K. K.; JOCOBS, J.; PITTMAN, M. E.; BORKO, H. Strategies for building mathematical communication in the middle school classroom: modeled in professional development, implemented in the classroom. **Current issues in middle level education,** Arizona, *11*, 1-12, 2005.

GREENES, C.; SCHULMAN, L. Communication processes in mathematical explorations and investigations. In P. C. ELLIOT, & M. J. KENNEY (eds.), **Communication in mathematics, K-12 and beyond.** Reston: NCTM . 1996. (p.p 219-230).

HAYATI, P.; SUTIARSO. S.; DAHLAN, S. Analysis of mathematical communication skills of junior high school students reviewed from gender and school origin. **Advances in Social Science, Education and Humanities Research**, *422*, 147-151, 2019.

HILL, F.; MAMMARELLA, I. C.; DEVINE, A.; CAVIOLA, S.; PASSOLUNGHI, M. C. Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. **Learning and Individual Differences**, Luxembourg, *48*, 45-53. Available: https://www.sciencedirect.com/science/article/abs/pii/S1041608016300164?via%3Dihub. Access : 4 sep. 2023.

HOORFAR, H.; TALEB, Z. Correlation between mathematics anxiety with metacognitive knowledge. **Procedia -** Social and Behavioral Sciences, Luxembourg, *182***,** 737-741, 2015.

INPRASITHA, M.; PATTANAJAK, A.; INPRASITHA, N. A study of student's mathematical communication in teacher professional development. **Journal of Modern Education Review**, Washington, *2*, 38-46, 2012.

IONESCU, C. E. Directions for action in oral communication towards the efficientization of the communication process. **Procedia -** Social and Behavioral Sciences, Luxembourg, *180*, 1620- 1627, 2015.

KARGAR, M.; TARMIZI, R. A.; BAYAT, S. Relationship between mathematical thinking, mathematics anxiety and mathematics attitudes among university students. **Procedia -** Social and Behavioral Sciences, Luxembourg, *8*, 537-542, 2010.

KLOCHKOVA, O.; KOMOCHKINA, E.; MUSTAFINA, A. "Triad" strategy as an effective way of

CC BY
ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

developing professional communication skills of physics and mathematics students. **Procedia** - Social and Behavioral Sciences*,* Luxembourg, *236*, 271-276, 2016.

KVEDERE, L. Mathematics self-efficacy, self-concept and anxiety among 9th grade students in Latvia. **Procedia -** Social and Behavioral Sciences, Luxembourg, *116*, 2687-2690, 2014.

LEE, J. M. **Some remarks on writing mathematical proofs**. Washington: University of Washington, 2012. Available: https://www.math.washington.edu/~lee/Writing/writing-proofs.pdf. Access : 5 sep. 2023.

MIER, H. I. V.; SCHLEEPEN, T. M. J.; BERG, F. C. G. V. D. Gender differences regarding the impact of math anxiety on arithmetic performance in second and fourth graders. **Frontiers in Psychology**, Switzerland *9*, 1-13, 2019.

MILLER, H.; BICHSEL, J. Anxiety, working memory, gender, and math performance. **Personality and Individual Differences**, Luxembourg, 37, 591-606, 2004.

MINISTRY OF EDUCATION. **A guide to effective instruction in mathematics, kindergarten to grade 6, Problem Solving and Communication**. Toronto: Ontario Association for Mathematics Education, 2005.

MUTAWAH, M. A. A. The influence of mathematics anxiety in middle and high school students math achievement. **International Education Studies***,* Ottawa, *8*, 239-252, 2005.

NAMKUNG, J. M.; PENG, P.; LIN, X. The relation between mathematics anxiety and mathematics performance among school-aged students: A meta-analysis. **Review of Educational Research Month 201X**, New York, *20*, 1-38, 2019. Available: https://www.jstor.org/stable/45277280?typeAccessWorkflow=login. Access : 4 sep. 2023.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS - NCTM. **Principles and standards for school mathematics.** Reston: The National Council of Teacher of Mathematics, Inc., 2000.

The Organisation for Economic Co-operation and Development-OECD. **PISA 2018 Results: *What Students Know and Can Do.*** Paris: OECD Publishing, 2019.

OZCAN, Z. C.; GUMUS, A. E. A modeling study to explain mathematical problem solving performance through metacognition, self-efficacy, motivation, and anxiety. **Australian Journal of Education** 0(0) 1–19. DOI: 10.1177/0004944119840073, 2019.

POURDAVOOD, R. G.; WACHIRA, P. Importance of mathematical communication and discourse in secondary classrooms. **Global Journal of Science Frontier Research: Mathematics and Decision Sciences**, *15*, 8-20, 2015.

QOHAR, A.; SUMARMO, U. Improving mathematical communication ability and self regulation learning of junior high students by using reciprocal teaching. **IndoMS. J.M.E**., Jakarta, *4*, 59-74, 2013.

RECTOR, N. A.; BOURDEAU, D.; KITCHEN, K.; MASSIAH, L. J. **Anxiety disorders An Information Guide**. Ottawa: Center for Addition and Mental Health, 2008.

SARI, D. M. Analysis of students' mathematical communication ability by using cooperative learning talking stick type**. Journal of Mathematics Education**, Jakarta, *6*, 183-194, 2017.

SCHWARTZ, S. **Abnormal Psychology: a discovery approach**. New York: Mayfield Publishing Company, 2000.

CC BY

ISSN 1980-4415
DOI: http://dx.doi.org/10.1590/1980-4415v37n77a18

SIREGAR, A. S.; SURYA, E.; SYAHPUTRA, E.; SIRAIT, A. R. The improving mathematical communication ability and students' self-regulation learning through realistic mathematical approach based on Batak Toba culture. **American Journal of Educational Research**, New York, 6, 1397-1402, 2018.

SPIELBERGER, C. D.; REHEISER, E. C. Assessment of emotions: anxiety, Anger, Depression, and Curiosity. **Psychology:** Health and Well-Being, New York, *1*, 271-302, 2009.

SUNDAYANA, R.; HERMAN, T.; DAHLAN, J. A.; PRAHMANA, R. C. I. Using ASSURE learning design to develop students' mathematical communication ability. **World Transactions on Engineering and Technology Education**, Makasar, *15*, 245-249, 2017.

TRIANA, M.; ZUBAINUR, C. M.; BAHRUN, B. Students' mathematical communication ability through the brain-based learning approach using autograph. **Journal of Research and Advances in Mathematics Education**, Surakarta, *4*, 1-10, 2019.

TRISNAWATI, T.; PRATIWI, R.; WAZIANA, W. The effect of realistic mathematics education on student's mathematical communication ability. **Malikussaleh Journal of Mathematics Learning (MJML), Aceh**, *1*, 31-35, 2018.

WIGFIELD, A.; MEECE, J. L. Math anxiety in elementary and secondary school students. **Journal of Educational Psychology**, New York, *80*, 210-216, 1988.

WILLIAMS, L. M.; KEMP, A. H.; FELMINGHAM, K.; LIDDELL, B. J.; PALMER, D. M.; BRYANT, R. A. Neural Biases to Covert and Overt Signals of Fear: Dissociation by Trait Anxiety and Depression. **Journal of Cognitive Neuroscience**, Massachusetts, *19*, 1595-1608, 2007.

YANG, E. F. Y.; CHANG, B.; CHENG, H. N. H.; CHAN, T. W. Improving pupils' mathematical communication abilities through computer-supported reciprocal peer tutoring. **Educational Technology & Society,** London, *19*, 157-169, 2016.

YENILMEZ, K.; GIRGINER, N.; UZUN, O. Mathematics anxiety and attitude level of students of the faculty of economics and business administrator; The Turkey Model. **International Mathematical Forum**, Ottawa, v. 2, n. 41, p. 1997-2021, 2007.

ZAKIRI, I. K.; PUJIASTUTI, E.; ASIH, T. S. N. The mathematical communication ability based on gender difference on students of XI grade by using problem based learning model assisted by probing prompting technique. **Unnes Journal of Mathematics Education, Semarang**, *7*, 78-84, 2018.

Submetido em 26 de Maio de 2022.
Aprovado em 08 de Abril de 2023.