

The Quality of Mathematics Teaching Aids Developed by Mathematics Pre-Service Teachers in Indonesia

Naufal Ishartono¹, Ikhsan Dwi Setyono¹, Ade Risma Maharani¹, Suliadi Firdaus bin Sufahani²

¹Department of Mathematics Education, Universitas Muhammadiyah Surakarta, Indonesia

²Department of Mathematics, Universiti Tun Hussein Onn Malaysia, Indonesia

*Corresponding author's email: naufal.ishartono@ums.ac.id

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ABSTRACT

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Mathematics teaching aids play an essential role in the learning process, where these aids become a bridge in the transfer of knowledge between teachers and students. The good of mathematics learning media will affect the transfer of knowledge from teacher to student. Therefore, this study aims to analyze and describe the quality of mathematics teaching aids developed by pre-service mathematics teachers in Indonesia, specifically those in the Mathematics Education Department of Universitas Muhammadiyah Surakarta. This study uses descriptive analytical studies in which the data obtained is analyzed quantitatively and described qualitatively. This study concludes that, in general, the quality of mathematical teaching aids developed has been categorized as at least "good enough" both in pedagogical and conceptual aspects and in physical aspects. However, some points need notable improvement and attention by the teaching lecturers at the point of the level of quality of safety and the quality of the teaching's ability aids in providing stimulus to students.

Keywords: *Teaching Aids Quality, Mathematics Education, Education Technology*

INTRODUCTION

School mathematics has very diverse functions in everyday life, especially in matters relating to problem-solving. The problems are not problems that can be solved by physical skills but instead by brain skills. Mathematical work objects are abstract objects closely related to human brain skills (Suharjana, 2009). Another benefit of school mathematics is that school mathematics can form positive characters for students, such as honesty, confidence, perseverance, responsibility, and procedural thinking (Prabowo & Sidi, 2010). By looking at the importance of these benefits in daily life, school mathematics becomes very necessary to master.

A school is a place where many school mathematics learning is taught. According to the 2013 Curriculum, in Indonesia, school mathematics has been taught since the grade 1 elementary school level, where the learning process ideally begins with recognizing concrete objects first, such as how to introduce the concept of a plane and the concept of numbers. Next, the students begin to be directed from mathematical learning based on concrete objects to mathematics learning based on abstract objects. In 12th grade, students in Indonesia can already think formally and work with abstract objects.

During the 12-year learning process, the teacher had many challenges in instilling school mathematics concepts with their students. One of the challenges is the brain ability of students in one class is very different (Chinn, 2016). Such as processing speed (ability to process information efficiently) (Kail & Salthouse, 1994), they were working memory capacity (capacity of the brain ability to store and maintain information (Cowan, 2005; Gathercole, Pickering, Knight, & Stegmann, 2004) and spatial thinking (how students can think spatially and knowing the concept of space) (Lee & Bednarz, 2009; Lock & Pouncett, 2017). Also, a mathematics teacher's challenge must be able to accommodate students who have different types of learning, such as visual, audiovisual, and kinesthetic learning. Therefore, a professional teacher must be able to accommodate challenges related to students' brain abilities and student learning types, one of the ways is by developing good mathematical teaching aids. Teaching aids are used to bridge information transfer. Teaching aids consist of tangible objects that help students learn abstract concepts in science as they enable students to visualize the concepts (Choi & Chang, 2004). The previous studies proved shows that by using teaching aids, teachers can teach their students comprehensively the studies conducted by Chou, et al. (2015), Sharma et al. (2015), and Rasid & Baharom (2012).

Mathematical teaching aids (MTA) must fulfill two aspects, namely 1) pedagogy and conceptual and 2) physical aspects (Sumardiyono, 2004). The details of those aspects can be seen in Table 1 (The Centre also uses the criteria for the Development and Empowerment of Educators and Educational Personnel In Mathematics (DEEEP in Mathematics) located in Yogyakarta, Indonesia).

Table 1. Criteria for Good Mathematics Teaching Aids

Pedagogic and Conceptual Aspect	Physical Aspect
1. The urgency level of the Mathematics Teaching Aids (MTA) compared to not using MTA	1. The level of strength of the MTA structure when used in the learning process
2. The level of accuracy of the concepts described in the MTA demonstration	2. The level of conceptual errors that might arise from MTA
3. The level of ease of students in understanding the concepts addressed through the MTA that has been developed	3. The level of the physical attractiveness of the MTA is for students who use it
4. The attraction of MTA in arousing student interest	4. The level of design quality (Precision/accuracy of the shape, size, and number) of the MTA that is based on the intended concept
5. Level of material variability that can be conveyed using MTA	5. The simplicity of the operation of the MTA is based on the intended mathematical concepts/ideas
6. The level of accuracy of the foundation used by MTA as an apperception for students	6. The simplicity of the MTA design (uncomplicated, easily duplicated, etc.)
7. Stimulations that MTA can give to students	7. The ease of MTA to move around
8. The level of possibility that students can find the concept of the MTA developed	8. The level of compatibility of physical MTA with students' physical competencies (can be seen, demonstrated, or moved by students)
9. The level of urgency of the concept that emerges from the MTA demonstration	9. The ease of the MTA to be saved
	10. The risk of MTA can harm students (sharp, easy to collapse, heavy, etc.)

Pedagogic and Conceptual Aspect	Physical Aspect
10. The level of possibility that students can carry out skill activities that are integrated (thinking, speaking, moving) with the MTA	11. Dryers of hazardous chemicals or radiation from MTA (flammable, pungent odor, irritation, etc.)
	12. Affordability of MTA prices by the public

The Mathematics Education Department of Universitas Muhammadiyah Surakarta, as one of the producers of prospective mathematics teachers in Indonesia, considers that it is essential to equip their students to understand and experience related to practical mathematics teaching aids. This was realized by holding a Practicum Course for the Making of the Mathematics Teaching Aids, which students can take it in the 7th semester. This course is divided into two parts: the planning part of the mathematics teaching aids and the making teaching aids. In the planning part, students in groups consisting of at least four people are asked to observe two schools on two levels, namely junior high and high school levels. From these observations, students were asked to analyze teachers' problems and obstacles in teaching school mathematics, especially in geometry, arithmetic-tic, statistics, and algebra. After analyzing the problem, the students are asked to determine the three titles of mathematical teaching aids, which later form the three titles will be discussed with the lecturer to choose which title can be realized as a mathematical teaching aid based on pedagogic conceptual aspects in Table 1.

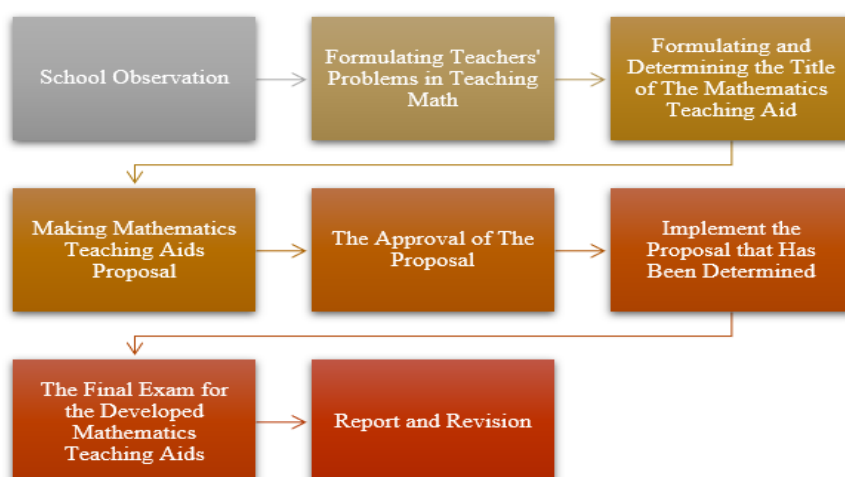


Figure 1. The Process of Making Mathematics Teaching Aids

This research aims to know whether the quality of the mathematics teaching aids developed by pre-service mathematics teachers in Universitas Muhammadiyah Surakarta has satisfied the essential quality of good mathematics teaching aids. Some previous research developed mathematics teaching aids, specifically the research conducted in Indonesia. However, those studies were not using the criteria of good-quality mathematics teaching aids (see Table 1) as the basis for developing the aids (Sunismi, 2015; Rajagukguk & Simanjuntak, 2015; Ishartono, Juniati, & Lukito, 2016)

Finish with selecting the title; students must make a proposal containing the theoretical, design, and budgetary funds needed to develop approved teaching aids. After the lecturer examines the proposal, students can enter the second part, i.e., making mathematics teaching

aids in accordance with the proposal approved by the lecturer. The illustration of the process can be seen in Figure 1.

This course will be ended up with an examination in the form of an exhibition of mathematical teaching aids. This examination format is used to facilitate examiners in assessing the quality of mathematics teaching aids developed by students. The assessment's basis refers to the quality of the mathematics teaching aids found in Table 1 with some modifications. In addition to getting assessments from examiners, students also get input from non-examining lecturers who attend in the exhibition to give input to students related to the mathematics teaching aids developed. After the exam is complete, students can improve the mathematics teaching aids they make based on their input during the previous mathematics teaching aids exhibition. Next, they report the results of their advanced teaching aids to the lecturers in the form of a final report. Based on the explanation, this study aims to analyze and describe the quality of mathematics teaching aids developed by mathematics education students at the Universitas Muhammadiyah Surakarta in the 7th semester of the 2019/2020 academic year.

METHOD

This study uses descriptive analytical studies that fundamentally identify and reflect trends and variations in populations, creating new measures of crucial phenomena, identifying causal effects, and descriptive analyses are part of almost every empirical paper and report. (Loeb et al., 2017). The course was taught by four lecturers of the Mathematics Education Department of the Universitas Muhammadiyah Surakarta, who have proficiencies in mathematics teaching aids and have been teaching this course for at least four years. In the exam, the four lecturers became examiners at the exhibition, where each lecturer was not allowed to test the students they were teaching. The number of teaching aids assessed was 46 pieces of mathematics teaching aids developed by 230 students in Universitas Muhammadiyah Surakarta. The students were in the seventh semester that passed pedagogical and professional teaching courses in the previous semesters.

The assessment technique in the test uses an assessment questionnaire designed by using the Google Form. It is because Google Form enables the lecturer to give a score easily (Mansor, 2011; Gehringer, 2010; Mattingly, Haas, Ramirez, & Fnp, 2018). The evaluation points used in the test were adopted from the criteria of an excellent mathematical teaching aid as in Table 1 by only taking six points on the pedagogical and conceptual aspects and five points on the physical aspects. The consideration in choosing these aspects is based on relevance to the Practical Course's objectives for the Development of the Mathematics Teaching Aids. The assessment points in question can be seen in Table 2.

Table 2. Item for Assessment of Mathematics Teaching Aids

The aspect of Pedagogic and Conceptual	Physical Aspect
1. The urgency level of Mathematics Teaching Aids (MTA) helps students learn the intended mathematical concepts compared to not using MTA.	1. The level of physical strength of the MTA that has been developed
2. The accuracy of the concepts conveyed using MTA has been developed.	2. Design quality (Precision or accuracy of the shape, size, and number) of the MTA based on the intended concept
3. Students' level of ease and clarity to capture the concepts or mathematical ideas that are intended from the demonstration of the Mathematics Teaching Aids that have been developed.	3. The simplicity of the operation of the MTA is based on the concept or idea of the intended mathematics
	4. The level of ease of Mathematics Teaching Aids to be moved to another place
	5. The risk of MTA can harm students (sharp, easy to collapse, heavy, etc.)

The aspect of Pedagogic and Conceptual	Physical Aspect
<ol style="list-style-type: none"> 4. The attraction of the MTA is to arouse students' interest in learning concepts or mathematical ideas 5. The degree of variability in the use of MTA in terms of variability in concepts or mathematical ideas 6. Stimulation that MTA can give to students to carry out reflection activities 	

The technique of assessing mathematical props uses the Semantic Differential Scale from 1-10. The Semantic Differential Scale is a tool for measuring respondents' attitudes or feelings that may not be expressed through traditional survey questions (Burns & Burns, 2008). Using this scale, researchers can see how strong the examiner's attitude towards the feasibility of mathematical teaching aids developed by students. The Differential Semantic Scale method is used in some studies, such as a study conducted by Palu. et al. (2017), which uses this scale to examine the comparison between context and laboratory test conditions for office chairs' rolling sounds. Alina Ciabuca (2014) uses this scale to assess citizens' perceived image of the Roman police force and many more uses at this time in research (Scott & Rowland, 1970; Pizzingrilli & Antonietti, 2010). Therefore, using the Differential Semantic Scale as a scoring scale in the examination is proper. Based on the assessment results carried out by examiners, it will be seen how many mathematical teaching aids have good quality and what aspects of mathematics teaching aids need to be improved.

The assessment scores are processed by dividing the Semantic Scale Differential 1-10 scale into two parts, namely 1-5 categorized as having a categorized level of "not very good" (value 1) to "not good" (value 5), while 6-10 having levels categorized as "good enough" (grades 6) to "very good" (value 10). The examiners' assessment scores are divided into two parts: those ranging from 1-5 and ranged 6-10. Next, the data is presented in the form of a diagram that only displays the percentage of data from a 6-10 scale to show that there are 46 (or 100%) teaching aids available and what percentage of the mathematics teaching aids are good quality.

This study's data are the results of the scores given by four examiners who assessed each mathematical teaching aid developed by students. The data is then analyzed by only taking the number of mathematical teaching aids that get a minimum score of "good enough" per each point assessed, both on pedagogical, conceptual, and physical aspects. Next, the score of mathematical teaching aids is converted into percentages and then presented in diagrams. The interview method is also carried out to sharpen the data obtained from examiners and data triangulation. The interviewees were from the examiners who gave grades, lecturers who guided students, and students who developed mathematics teaching aids. Interviews are conducted after the researcher has finished analyzing the scores obtained from the examiners' assessment results.

RESULTS & DISCUSSION

The mathematics teaching aids exhibition was held on January 4th, 2019, at the M. Djazman Auditorium, Universitas Muhammadiyah Surakarta, Indonesia. The exhibition was attended by 46 student groups consisting of at least four students and some guests. Following is some documentation related to the exhibition on mathematics teaching aids developed by students. The documentation of the exhibition can be seen in Figure 2.

Result

The aspect of Conceptual and Pedagogy

According to this aspect of conceptual and pedagogy, from 100% or 46 mathematical teaching aids developed by students, most mathematical teaching aids developed by the students have good levels of quality in pedagogical and conceptual aspects (See Figure 3.). The point that still needs to be improved is at the point of the level of stimulation given by MTAs to make students want to learn the intended concept, where the number of minimum quality teaching aids in the "good enough" category is around 84%. This means that as many as 16% or as many as 7 mathematics teaching aids do not have good quality to stimulate students to be able to learn. In detail, the assessment results at this point can be seen in the following Figure 3.



Figure 2. Mathematics Teaching Aids Exhibition

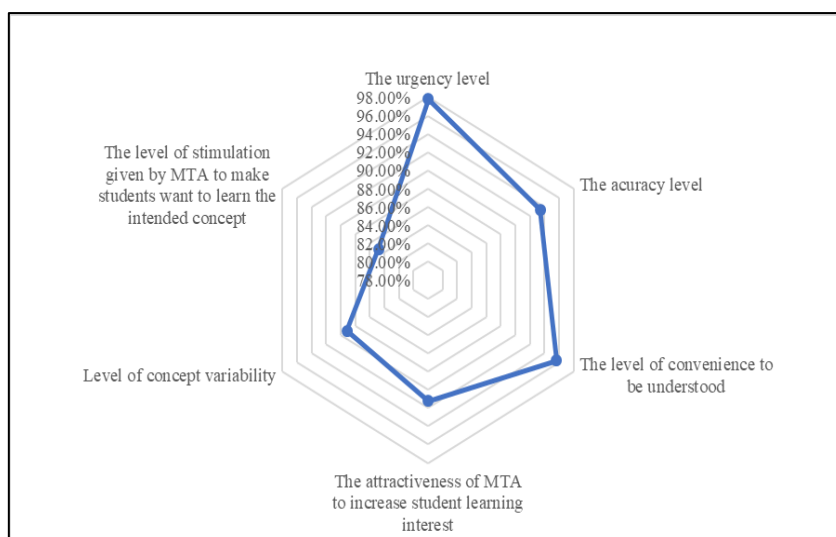


Figure 3. The quality level of the pedagogical and conceptual aspect

As many as 32 teaching aids have been classified as almost very good; even one mathematics teaching aid is "very good". Otherwise, one teaching aid was categorized as "not very good" in stimulating students to learn. The details can be seen in Figure 4.

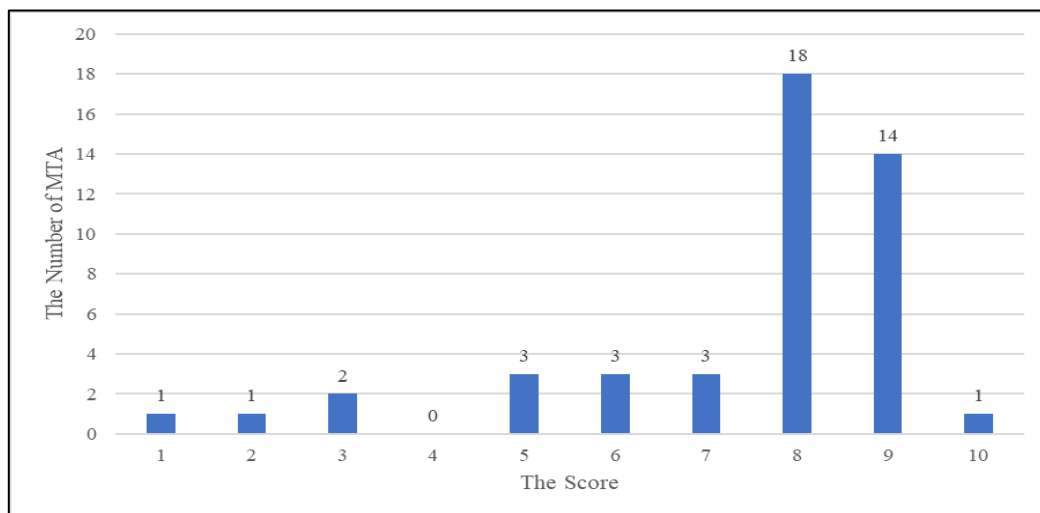


Figure 4. The score of stimulation level given by the MTAs

While the most prominent points from the six points in the pedagogical and conceptual aspects assessed are on the points of the urgency level of MTA, at this point, the number of mathematics teaching aids categorized as at least "good enough" is around 97%. It means that 45 developed teaching aids are following their development objectives, namely as a teacher's aids in explaining the mathematical concepts to be taught. In detail, these points can be seen in Figure 5.

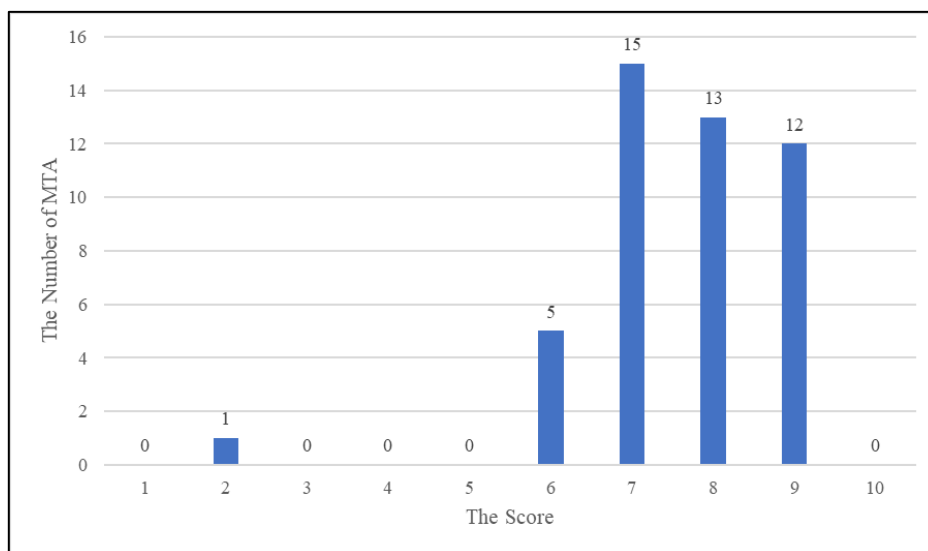


Figure 5. Point of the urgency level of MTA

Physical Aspect

The physical aspect of mathematics teaching aids is considered one of the essential aspects to be assessed as this determines the look and safety of the aids to be used. The assessment of the physical aspects by the examiners on mathematics teaching aids can be seen in Figure 6.

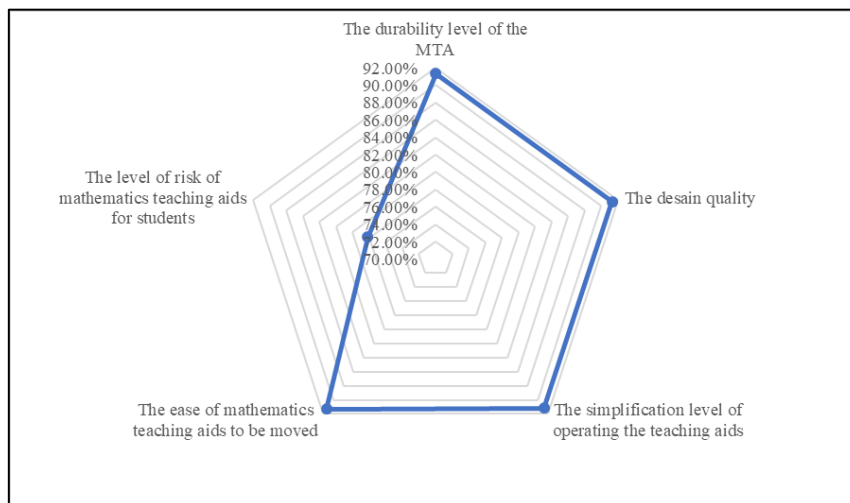


Figure 6. The Quality Level of Physical Aspect

According to Figure 6., in general, the quality of mathematical teaching aids in terms of physical condition is already good, of which the overall points are assessed; the majority of teaching aids are already in the minimum category of "good enough." However, some aspects still need more attention, namely the risk of mathematics teaching aids for students. From Fig 6., the number of mathematics teaching aids categorized as at least "quite good" reached around 78%. It means that as many as 22% or ten pieces of mathematics teaching aids developed do not have a good safety quality.

Eight teaching aids were considered to be very dangerous. It can endanger students or even teachers if used in the learning process. Of course, many factors that make the mathematics teaching aids that have been developed are considered unsafe for students where one of which, according to the examiners, is the lack of neatness in the installation of components of mathematical teaching aids such as nails, zinc, wood that is not smooth, even messy cable arrangement and there is an opened copper in the wire. The detail of the numbers can be seen in Figure 7.

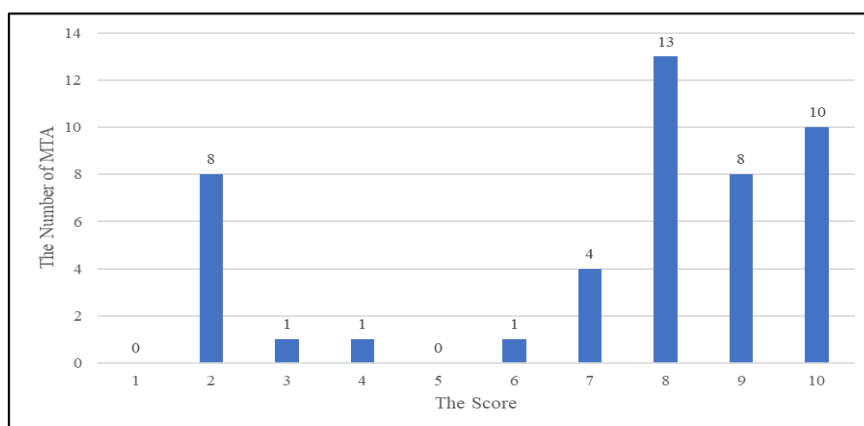


Figure 7. The Risk Level of The Mathematics Teaching Aids

Discussion

The good quality of mathematics teaching aids can be a critical factor in the success of classroom learning. Objects of work in mathematics that are abstract become very difficult to understand if delivered only verbally. Therefore it is necessary to have a good mathematics teaching aid to help mathematics teachers deliver their material properly and correctly (Ahmed et al., 2004). Therefore, based on Table 2, the quality of mathematics teaching aids developed by the students from the Mathematics Education Department of Universitas Muhammadiyah Surakarta was assessed based on two aspects: Physical Aspect and Aspect of Conceptual and Pedagogy.

The aspect of Conceptual and Pedagogy

For conceptual and pedagogy, the "urgency level" point attained the highest average score by the examiners. All aids developed by the students were based on their school observations, as shown in Fig 1. The next aspect which gained the highest average score is that aspect of "convenience level to understand the taught topic". Most of the developed teaching aids (96%) successfully attained the qualification of the aspect. Based on the students and their lecturer's confirmation, the lecturer set the condition of the aids that would be developed by the students, which had to be easy to move and use. Therefore, this is sensible that most of the aids gained the aspect. While those who did not reach the aspect due to the composition of the parts used in the teaching aids were complicated and were not easy to use, it would make it difficult for students to understand the material being taught. Fig 8. is the sample of an aid that did not pass the aspect entitled PATRIKS stands for *Papan Matriks* or Matrix Board. The figure's aid had many components that were considered would make it difficult for teachers to use it or make it difficult for students to manipulate it, such as the electrical components placed at the top of the board.

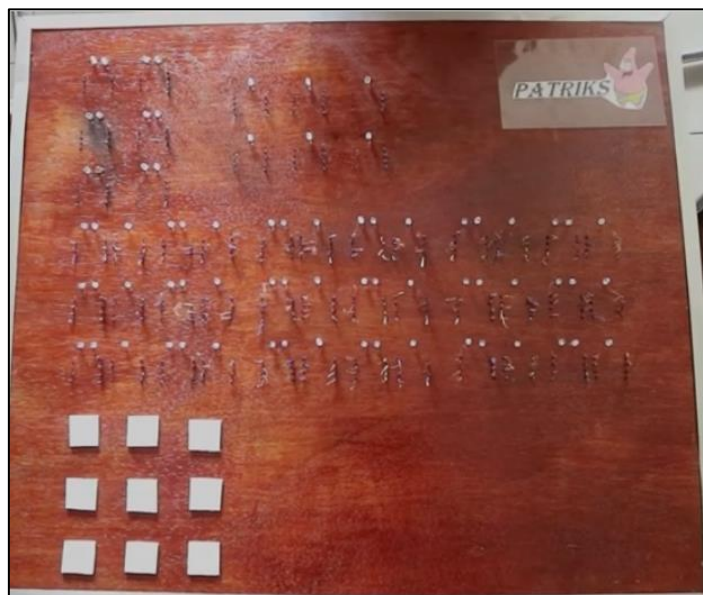


Figure 8. The sample of an aid does not satisfy the "convenience level " aspect to understand the taught topic."

The third aspect is the accuracy level, which is how mathematics teaching aids can be used as a medium to help teachers explain mathematical concepts precisely and clearly without having an ambiguous thing. This aspect can be fulfilled by most of the developed mathematics

teaching aids because, as was confirmed by the students, the lecturers guide them along the development process to keep on track, which means suitable with the topic modeled by the developed mathematics teaching aids. The aid in Figure 8. is one example of the aid that meets a good accuracy degree. Although students in mathematics education study programs did not get courses related to electricity, supervisors are also involved in guiding students to make and ensure electrical components are arranged and work as desired. The developed aid can be used accurately to teach the topic of a matrix.



Figure 9. A sample of mathematics teaching aids which has more than one variability of concepts that can be delivered

The next aspect is the concept variability, which is the ability of a mathematics teaching aid that can enable the teachers to use it to explain more than one mathematics topic. Of the 46 MTAs developed, almost 86% of MTAs received a "good enough" score from the examiners. According to one of the testers, "MTA gets the value because its use the teacher can use it to explain various concepts" while pointing towards MTA as in Figure 9. As a result, "This MTA can help teachers on the concept of geometry transformation and fundamental concepts such as the introduction of coordinates and straight-line equations".



Figure 10. A sample of mathematics teaching ads which has a good quality of stimulation

However, the aspect that still becomes a homework is the stimulus point, namely how mathematics teaching aids should be able to make students interested in learning mathematics by using it and further than that is how the aids can attract students to think critically. Theoretically, the point of stimulation that emerged by the MTA is necessary to be fulfilled in education, as when the brain gets a new stimulus, the brain will learn something new (Chamidah, 2009). That means whenever the MTAs are used in class; the MTA will emerge students' willingness to study. Therefore, the teaching aids that do not fulfill the point need to be improved or even reproduced. A sample of mathematics teaching aids that the examiners consider to have a good quality to stimulate students to learn can be seen in Figure 10.

The mathematics teaching aid entitled "Kotak Matriks" or Matrix Box that is depicted in Fig 10. was considered one of the mathematics teaching aids that are qualified to stimulate students to learn matrix by the examiners. According to them, in terms of learning stimulation, this aid has a good combination of light colors like red, blue, green, and orange, making people who see the colors become interested, especially the color of red. It is in line with the study done by Kuniecki, Pilarczyk, & Wichary (2015), which stated that the choice of color would significantly affect the people who see it, especially the red color which has a significant influence on people's interest to see it.

Besides considering color, the aspect of technology embedded in the developed teaching aid is also considered to trigger students to pay attention to the mathematics teaching aid. The Kotak Matriks used electrical lamps, which are set according to the logic and algorithm of matrix calculation. The teachers can turn on the light when the way to answer or the answer is correct. Otherwise, the lamps can be turned off when the answer is incorrect. The existence of lights in the aid can be the center of attention for students (Painter, 1976).

The aspect of Physical Condition

Physical aspects are fundamental to note because this affects safety and comfort during its use to teach mathematical concepts. Also, the physical aspects affect the durability of the MTA developed. From this aspect, it is noticeable from Fig 6. that some mathematics teaching aids lack safety. It should be paid special attention to because the safety aspect of mathematics teaching aids must be fulfilled in developing mathematical teaching aids, which will prevent the students from getting injured. Therefore, improving the quality of the safety of mathematical teaching aids developed by students needs to be increased as much as possible to be at the minimum category level, which is "good enough". The MTA on Fig 8. was one of those MTA that lacked safety because the cooper of the wires installed in the MTA popped up and risked the students or teachers if they intended to use it. The result of the confirmation by the group of students who developed the MTA was that they still believed the MTA they had developed was safe enough to be used if it was repaired from the neatness of the electronic devices installed in the MTA. From the side of the accompanying lecturer, "the MTA is safe enough to be used as long as the copper that appears on the board's surface can be tidied up and coated with masking tape". Based on the confirmation results from the three parties, it can be concluded that although the MTA in Fig. 8. is considered to have a high risk to users, the MTA can still be improved in terms of cabling so as not to cause the risk of being electrocuted. Because, in principle, the MTA developed must be safe to use (Alshatri et al., 2019).

On the side of durability, design quality, portability, and simplification, the 46 MTAs developed all have almost the same percentage, around 92%. After being confirmed to the supervisor, the minimum of all MTAs developed must have sufficient minimum durability,

portability, and simplification level standards so that the developed MTA can be classified as suitable for use.

CONCLUSION

In conclusion, the quality of most mathematics teaching aids developed by students of the Department of Mathematics Education at the Universitas Muhammadiyah Surakarta in the 7th semester has been considered good and feasible to use and implement. However, some points need more attention, such as the level of stimulation given by the developed mathematics teaching aids to make students want to learn the intended concept. Next, the risk level of the developed mathematics teaching aids for students is considered harmful to be used by the students and teachers. This investigation research conducted at the Mathematics Education Department of the Muhammadiyah University of Surakarta is expected to be able to add views and references for lecturers and students who will develop mathematics teaching aids where physical aspects, as well as conceptual and pedagogical aspects, must be fulfilled, especially at the stimulus and security points for students to use it.

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