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Effects of the Geogebra-assisted Missouri mathematics project learning model on students' mathematical communication ability

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ABSTRACT

The purpose of this study was to find the effects of GeoGebra- assisted Missouri Mathematics Project (MMP) learning model on students' mathematical communication abilities. The study can be categorized as a quantitative experimental research type with a quasy-experimental design. The research population refers to all grade X Physics students of private Senior High School in South Tangerang. The purposive sampling technique was used to a sample size of 38 students as the experiment group and another 34 students as the control group. Data were collected using a descriptive test of mathematical communication ability on the material of the three-variable linear equation system. Further, the t-test was used to analyze the data. Findings showed that the GeoGebra-assisted MMP learning model improves the students mathematical communication abilities at the moderate category.

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INTRODUCTION

Mathematical communication is an important ability that must be developed by students (Luritawaty, 2018). Similarly, Ahmad & Nasution (2018) stated that communication in mathematics becomes one of the essential abilities required for students since mathematical communication abilities play an essential role in assisting students to communicate their thoughts about the subjects they learn. Furthermore, Greenes & Shulman in Saragih (2007) explained that the communication of mathematics is a stimulus for students in developing strategies and methods for solving mathematical problems; the primary capital for students in solving mathematical problems becomes a forum where students can interact with friends to evaluate and refine mathematical ideas.

Mathematical communication skills are students' skills to realize, interpret, and explain mathematical symbols both in writing and orally (Khadijah *et al*., 2018). However, the fact is that currently, mathematical communication abilities owned by students in Indonesia are relatively low (Rosyid & Umbara, 2018). This follows the opinion of Natawijaya in Aden (2011) which states that most of the students' difficulties when learning mathematics are caused by their low mathematical communication skills. Furthermore, the process of a two-way communication interaction between students and teachers which is continuous can enhance students' mathematical communication abilities (Astiswijaya, 2020).

There is a systematic learning model for the growth of mathematical concepts and ideas through individual and group training. This learning model is known as the Missouri Mathematics Project

(MMP). In the MMP, students do not only step in as objects but as active subjects (Kurniasari *et al*., 2015). In the MMP leaming model, students are emphasized to function in the learning process because teachers are present solely as guides (Savitri *et al*., 2013). The MMP also helps students to be able to exchange ideas with each other in cooperative work steps (Jannah *et al*., 2013). According to Krismanto in Mariyam *et al*. (2018), in its execution, the MMP leaming model has five stages: namely review, development, controlled training, seatwork, and assignments.

The purpose of implementing the MMP is to improve students' interpersonal communication, decision-making, and problem-solving skills. In addition, project assignments also provide students with the opportunity to solve specific problems (Sutarman *et al*., 2014). Furthermore, Rahman & Nasryah (2020) stated that the MMP learning model is effective when implemented in the learning process and gains affirmative responses from students. Besides, in the current era of technological development, several technologies used in learning should be integrated with other leaming models to achieve the learning objectives (Rosyid & Umbara, 2018). Splittgerber & Stirzaker in Sunarto (2011) stated that the use of technology as a learning medium makes learning time much more effective. GeoGebra, for example, is learning medium software on the computer that can be used as an instructional medium to help with the process of mathematics learning.

GeoGebra was first developed in 2001 by Markus Hohenwarter. Hohenwarter in Rahadyan *et al.* (2018) stated that GeoGebra is a computer software that functions to teach mathematics, especially in algebra and geometry. GeoGebra can help students actively understanding algebra and geometry by simply visualizing geometric concepts, making it easier for students to create and find mathematical expressions. As for some of the benefits of GeoGebra, as described by Hohenwarter & Fuch, GeoGebra can be used as a construction aid, media presentation and visualization, discovery process aids, and communication and representation tool (Suhaifi *et al*., 2021). Suciati & Mailili (2022) stated that the application of GeoGebra as a learning medium has a positive effect on increasing students' mathematical abilities in the learning process. Then, GeoGebra can also be utilized in the implementation of learning by integrating it with learning models and approaches such that there is an enhancement of students' mathematical ability (Suciati & Mailili, 2022). The mathematical abilities, in this case, include understanding ability, communication ability, problem-solving ability, connection ability, and reasoning ability.

Previous research on the implementation of MMP has shown positive results in terms of students' critical thinking, problem solving, and the ability to communicate mathematically. Some of the previous studies include a study by Wahyuni & Efuansyah (2018) titled "Pembelajaran Missouri Mathematics Project (MMP) Menggunakan Strategi Think Talk Write (TTW) terhadap Kemampuan Berpikir Kritis dan Kemampuan Pemecahan Masalah" [The Effects of Missouri Mathematics Project (MMP) Learning Using Think Talk Write (TTW) Strategy on Critical Thinking Skills and Problem-Solving Skills]. The results of this study showed an improvement in the average score of critical-thinking skills and problem-solving skills up to the “good” category after the implementation of MMP with the Think Talk Write (TTW) strategy. Another study is by Ulya & Hidayah (2016) titled "Kemampuan Pemecahan Masalah Ditinjau dari Self-Efficacy Siswa dalam Model Pembelajaran Missouri Mathematics Project" [Problem-solving Skills Viewed from students' Self-efficacy in MMP Model]. The findings showed that the MMP model effectively influences problem-solving skills from the perspective of students' self-efficacy or self-confidence. And, a study by Handayani *et al*. (2018) titled "The effects of Missouri mathematics project learning model on students' mathematical problem-solving ability" indicated that there is influence of the MMP on the problem-solving skills of junior high school students.

However, there is yet no research to specifically investigate the effects of the MMP learning model assisted by GeoGebra on the students' mathematical communication abilities. Based on the description above, the researcher of the present study is interested in studying the MMP learning, assisted by Geogebra, in relation to students mathematical communication abilities. The study integrates GeoGebra with the Missouri Mathematics Project learning model as an instructional medium focusing on students' mathematical communication abilities. The aim of the study is to investigate the influence of using the MMP learning model assisted by GeoGebra towards students' mathematical communication abilities.

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METHOD

The study used the quasi-experimental method with an experiment research group and a control group. The experiment group is subjected to the research treatment of the GeoGebra-assisted MMP learning model; the control group does not receive the treatment. The scheme fits the description of a non-equivalent post test-only group design, which can be illustrated by Figure 1.

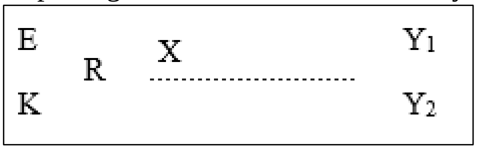

Figure 1. Reseacrh design of the present study

Information:
R : Both classes are chosen randomly.
X : Treatment in the experimental group through the MMP learning model with the help of GeoGebra.
Y_1 : Post-test in the experimental group.
Y_2 : Post-test in the control group.

The population of the study referred to all Year X Physics students of the Senior High School, South Tangerang, who were enrolled in the 2022/2023 school year. Sampling was done by the purposive sampling technique. The sampling technique placed Class Physics 4 as the experiment group and Class Physics 3 the control group. Data were obtained by a test serving as the research instrument. The instrument test consisted of a set of question items to test mathematical communication abilities. The test instrument was developed from the learning material consisting of the three-variable linear equation system with GeoGebra assistance. The instrument was ultimately used as the post-test to the study, administered to test the mathematical communication ability achievements of the students in the two research groups to compare between the students who received the MMP research treatment and those who received conventional learning activities.

The post test on the ability of mathematical communication, furthermore, consisted of five descriptive questions, each of which contained several mathematical communication ability indicators by NCTM in Hikmawati *et al*. (2019). The mathematical communication ability indicators are presented in Table 1, indicators and questions of the mathematical communication skill test are shown in Table 2.

Table 1. Mathematical communication ability indicators

Aspects	Description
Written Text Express ideas, situations, and mathematical relatedness through writing.	a. Identifying any information found in the exercise. b. Identifying items that are posed in the problem. c. Writing down the idea of the solution strategy using one's own language appropriately and easily understood. d. Describing ideas using mathematical terms
Drawing Describe mathematical ideas in visual forms (pictures, tables, or diagrams).	a. Presenting mathematical problem conditions, concepts, or solutions in the form of visualizations appropriately. b. Presenting mathematical problem conditions, concepts, or solutions in the form of pictures with clear intentions.
Mathematical Exspression Describe a problem idea, situation, picture, or tangible object into symbol language, mathematical models / mathematical expressions.	a. Explaining ideas and situations correctly and completely by using mathematical models. b. Expressing ideas correctly by using the correct mathematical symbol/notation language. c. Using all the information available in the problem precisely. d. Drawing conclusions that are appropriate.

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Table 2. Indicators and questions of the mathematical communication skill test

No	Material Indicator	Ability Indicator	Question
1	Solve the problem using the substitution method	*Written Text*, *Drawing*, and *Mathematical Expression*	Rudi, Ilham, and Adi went to a fruit shop. Rudi bought 2 kg of mangosteen and 3 kg of apples for Rp. 138,000. Ilham bought 1 kg of mangosteen, 2 kg of apples, and 1 kg of oranges for Rp. 100,000. Meanwhile, Adi bought 2 kg of mangosteen, 1 kg of apples, and 3 kg of oranges for Rp. 126,000. Determine the price for purchasing 2 kg of mangosteen, 1 kg of apples, and 1 kg of oranges. Solve using the substitution method and draw a graph of the mathematical model formed using Geogebra.
2			Ibu Ani bought 5 kg of eggs, 2 kg of meat, and 1 kg of shrimp for Rp. 305,000. Ibu Lina bought 3 kg of eggs and 1 kg of meat for Rp. 131,000. Ibu Siti bought 3 kg of meat and 2 kg of shrimp for Rp. 360,000. If Ibu Eka bought 3 kg of eggs, 1 kg of meat, and 2 kg of shrimp, determine the selling price for each 1 kg of eggs, 1 kg of meat, and 1 kg of shrimp. Solve using the substitution method and draw a graph of the mathematical model formed using GeoGebra.
3	Solve the problem using the elimination method		Arif, Ridho, Udin, and Ahmad went shopping at a bookstore. Arif bought 2 ballpoint pens, 1 pencil, and 1 eraser for Rp. 9,400. Ridho bought 1 ballpoint pen, 2 pencils, and 1 eraser for Rp. 8,600. Udin bought 3 ballpoint pens, 2 pencils, and 1 eraser for Rp. 14,200. Determine the price for purchasing 1 ballpoint pen, 3 pencils, and 2 erasers. Solve using the combined method (elimination and substitution) and draw a graph of the mathematical model formed using Geogebra.
4			Rachel, Alya, and Irliana went together to a fruit shop. Rachel bought 2 kg of apples, 2 kg of oranges, and 1 kg of mangoes for Rp. 160,000. Alya bought 3 kg of apples, 1 kg of oranges, and 1 kg of mangoes for Rp. 170,000. And Irliana bought 1 kg of apples, 3 kg of oranges, and 2 kg of mangoes for Rp. 190,000. Determine the selling price for 1 kg of apples, 1 kg of oranges, and 1 kg of mangoes. Solve using the elimination method and draw a graph of the mathematical model formed using GeoGebra.
5	Solve the problems using combined methods (elimination and substitution)		In a car tire factory, there are 3 machines, namely machine A, B, and C. If all three machines work, they will produce 340 car tires per day. If only machines A and B work, they will produce 215 car tires per day. If only machines B and C work, they will produce 230 car tires per day. Determine the production of each machine per day. Solve using the combined method (elimination and substitution) and draw a graph of the mathematical model formed using GeoGebra.

The research instrument were tested for validity and reliability first. The research instrument is considered good if it meets the validity and reliability tests. The pilot testing of the research instrument was conducted to obtain an empirical overview of whether the instrument is suitable for use before it is given to the research student subjects. First, expert validation was conducted to assess the content

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validity of the instrument. Expert validation was done by a lecturer from the Mathematics Education Program at Prof. DR. HAMKA Muhammadiyah University and a mathematics teacher from Senior high school in South Tangerang. Next, the mathematical communication ability test was tested for validity and reliability in the 11th grade class of private senior high school in South Tangerang. The results of the validity test are shown in Table 3 as follows.

Table 3. Calculation results validity testing

Number	r_{result}	r_{table}	Result	Information
1	0.638		$r_{result} > r_{table}$	Valid
2	0.461		$r_{result} > r_{table}$	Valid
3	0.722	0,396	$r_{result} > r_{table}$	Valid
4	0.686		$r_{result} > r_{table}$	Valid
5	0.606		$r_{result} > r_{table}$	Valid

According to the table above, each item tested for validity has a value of $r_{result} > r_{table}$, indicating that all items are considered valid. After the items are deemed valid, the next step is to test for reliability. The results of the reliability test using Cronbach's alpha formula show that $r_{result} = 0.687 > r_{table} = 0.396$, indicating that the mathematical communication ability test instrument is considered reliable. From the validity and reliability test results, the researcher concluded that the instrument of mathematical communication ability test is feasible to be used as a research instrument.

RESULTS AND DISCUSSION

Learning Activity in The Experiment Class

The experiment group of the study was the one that received the research treatment of the GeoGebra-assisted Missouri Mathematics Project (MMP) learning. The MMP model of instruction regularly emphasizes active student participation in the learning process because the MMP learning model offers the students more chances to work within the group and independently implement their knowledge in seatwork. The stages in conducting the MMP class are as follows:

1) Introduction/Review. The learning process began with a review of previously given material that had connection with the topic of today's discussion. This is a prerequisite for working on new questions. The teacher has a role in motivating students to initiate and raise the students' enthusiasm so that they can rebuild and are able to take part actively in the series of learning activities and practice questions. Review stage can be illustrated by Figure 2.

Figure 2. Review stage

2) Development. This stage is an instructional step to build on previous knowledge to better understand new materials or concepts. The learning process consists in explanation and discussion of the new materials to give the students insights of the process of solving the questions as an exercise. Development stage can be illustrated by Figure 3.

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Figure 3. Development stage

3) Cooperative Work. In this stage, the students are provided with some questions for completion by working within the group that has been prepared on the presentation of previous material. The teacher provides guidance and monitoring so that inaccuracies in concept understanding do not exist. Cooperative work stage can be illustrated by Figure 4.

Figure 4. Cooperative work stage

4) Independent Work/Seatwork. After students are able to carry out group activities in solving problems, they then develop the material through solving practice questions in an individual manner.
5) Completion. This is the last learning session, where students summarize the provision of material in the learning process and are given assignments to be completed at home.

In addition, this MMP learning process is combined with the GeoGebra software. The GeoGebra software acts as a learning medium used to facilitate students in visualizing mathematical objects and assist students in resolving math problems.

Results

The post-test scores of the students' mathematics communication abilities on the topic of three-variable linear equation system became the research data for this study. The experimental group included 38 students who were given the MMP learning model aided by GeoGebra as the reserch treatment, while the control group included 34 students who did not receive the treatment. Based on the data of post-test scores, frequency distribution tables were created as seen in Tables 4 and 5. Table 4 shows that the average score of the mathematical communication ability of students that were treated with GeoGebra-assissted MMP (Table 4) is higher than that of the students that were not treated with GeoGebra-assisted MMP (Table 5). As a result, it can be inferred that the MMP in mathematics instruction, aided by GeoGebra, has a good effect on students' mathematical communication abilities.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Table 4. Frequency distribution of posttest scores of the experiment class

No	Intervals	Real limit	Average	Middle value	Frequency		
					Absolute	Cumulative	Relative
1	48-56	47.5-56.5	73.184	52	3	3	7.9%
2	57-65	56.5-65.5		61	3	6	7.9%
3	66-74	65.5-74.5		70	14	20	36..8%
4	75-83	74.5-83.5		79	14	34	36.8%
5	84-92	83.5-92.5		88	3	37	7.9%
6	93-101	92.5-101..5		97	1	38	2.6%
		Total			38	138	100%

Table 5. Frequency distribution of posttest scores of the control class

Number	Intevals	Real limit	Average	Middle value	Frequency		
					Absolute	Cumulative	Relative
1	30-39	29.5-39.5	61.706	34.5	6	6	17.6%
2	40-49	39.5-49.5		44.5	2	8	5.9%
3	50-59	49.5-59.5		54.5	5	13	14.7%
4	60-69	59.5-69.5		64.5	6	19	17.6%
5	70-79	69.5-79.5		74.5	9	28	26.5%
6	80-89	79.5-89.5		84.5	6	34	17.6%
		Total			34	108	100%

According to the tables above, it can be seen that the majority of students in the experiment group obtained mathematical communication ability scores between 65.5 - 74.5 and 74.5 - 83.5, with a total of 14 students or 36.8%. The highest score, ranging from 92.5 - 101.5, was obtained by 1 student or 2.6%, while the lowest score was achieved between 47.5 - 56.5, with a total of 3 students or 7.9%. On the other hand, the majority of students in the control group obtained mathematical communication ability scores between 69.5 - 79.5, with a total of 9 students or 26.5%. The highest score, ranging from 79.5 - 89.5, was obtained by 6 students or 17.6%, while the lowest score was achieved between 29.5 - 39.5, with a total of 6 students or 17.6%.

In summary, the post-test average score of of students' abilities mathematical communications using the MMP learning model was 73.184 with a standard deviation of 10.75 and that of the students who studied without applying an MMP model was 61.70 with the standard deviation of 17.60. To determine the existence or non-existence of average differences caused by the effect of treatment, the data pre-requisite test is conducted which includes a homogeneity test and normality test. The calculated prerequisite tests are presented in Table 6 below.

Table 6. Results of analysis of prerequisite test calculation

Class	L_{result}	L_{table}	Information	F_{result}	F_{table}	Information
Experiment	0.104	0.142	Normal Distributed Data	2.682	1.75 2	Variances of Both Classes are Inhomogeneou s
Control	0.11		Normal Distributed Data			

From the results of the pre-requisite tests of data analysis that include homogeneity and normality (Table 6), it can be stated that both the class data are distributed normally and have an

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inhomogeneous variance. The can, therefore, proceed with the hypothesis testing procedure of the research using the *t*-test. The calculation results of the *t*-test obtained $a\ t'_{result} = 3.292 > 1.994 = t'_{table}$.

After recognizing that there exists an effect of using the MMP with GeoGebra on the mathematical communication abilities of students, so the next step is to examine the size of the effect in learning, to see whether the effect is in the low, medium, or high category. To find out the size of the influence, the effect size test was used. The calculation results of the size effect can be observed in Table 7 as follows.

Table 7. Results of the effect size calculation

Class	$\bar{Y}$	S	ES
Eksperiment	73.184	0,652	0.783
Control	61.706		

The results of the calculation of the effect size of the treatment influence (Table 7 above), the value of ES=0.783, indicates that the effect of the MMP leaming model assisted by GeoGebra on students' mathematical communication abilities is moderate.

Discussion

Based on the results of the hypothesis-testing conduct of the tudy, the H_0 hypothesis is rejected and the alternative hypothesis H_1 is accepted. Rejection of the H_0 indicates the presence of effects of the GeoGebra-assisted MMP model of learning on students' mathematical communication abilities. This is aligned with the results of the study conducted by Rahmi & Rahmi (2015) which stated that there were influences of the MMP learning assisted by Geogebra towards students' mathematical communication abilities on the topic of circle equations. Moreover, the research findings are aligned with the outcome of the previous study conducted by Huzaifah (2013) which mentioned the effects of the Missouri Mathematics Project on students' mathematical communication abilities on the subject matter of cubes and blocks.

After recognizing that there is an effect of using the MMP learning model with GeoGebra on the mathematical communication abilities of students, the next step is to examine the size of the effect in learning, to see whether the effect is in the low, medium, or high category. To do this, the effect size test is conducted. The results of the calculation of the effect size test showed that the value of ES=0.783 which indicates that the effect of the MMP leaming model assisted by GeoGebra on students' mathematical communication abilities is moderate. This is different from the results of Sari's study (2018) which stated that the influence of the application of MMP on students' mathematics communication abilities on subject material of statistics is included in the high category.

In particular, the effect of implementing the MMP learning model assisted by GeoGebra on students' mathematical communication abilities shows which group performs significantly better in mathematical communication abilities. The post-test score average for the control group is smaller than that of the experiment group (61.706 < 73.184). The higher posttest average score in the experiment group indicates that setudents in this group has better mathematical communication abilities than those in the the control group. This finding suggests that the implementation of the GeoGebra-assisted MMP learning model gives a positive impact on mathematical communication abilities. This is consistent with study conducted by Rosyid & Umbara (2018) which showed that the application of the Geogebra-assisted MMP learning model effectively enhances students' mathematical communication abilities.

The MMP learning model provides effective ways for students to use their time in learning, such as reviewing the material from previous lessons, developing new ideas as elaboration of the concepts in mathematics, providing problem exercises (group), and giving the students self-assignment. Furthermore, through exploring and developing new ideas and giving many practice problems, the students will be more creative and skillful in resolving many kinds of problems. In addition, the GeoGebra learning media application can also help the students in the learning process by simplifying students in visualizing the mathematical objects being studied. Therefore, students' mathematical communication skills in visualizing mathematical objects are getting better. This is in accordance with the research results which state that involving Geogebra in learning can enhance the ability of students' mathematical communication (Supriadi, 2015).

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The MMP learning model with its various learning stages is considered effective in encouraging students to be active in the learning process. This can be seen from the role of students in each stage of the MMP learning model. In the introductory/review stage, students are motivated by the teacher, which is certainly the main capital for building students' enthusiasm. In addition, in the introductory/review stage, students are given an overview of the connection between the material they have learned before and the material they will learn next. Then, in the development stage, students are given new material that will be a new insight for them. In the development stage, students are not only sitting and paying attention but are also given the opportunity to ask questions and conduct discussions in the learning process. This certainly encourages all students to participate actively during the learning process.

Learning using the MMP also encourages students to practice group discussions. This can be seen through the cooperative work stage in the MMP model, which provides students with the chance to work together in groups to resolve math problems. Of course, in this stage, students are trained to actively discuss materials, exchange ideas, and collaborate with their groupmates. Not only do they solve math problems in groups, but they also are the opportunity to solve math problems independently, that is, during the independent work/seatwork stage. The purpose of the independent work/seatwork stage is to see the extent of students' development in comprehending the subject matter in the process of learning. The various advantages of using the MMP model are considered to enhance the mathematics abilities of students, including their mathematical communication skills.

In addition, the use of GeoGebra software in mathematics learning processes is considered efficient in terms of time spent on drawing mathematical objects on the board and performing calculations. This is consistent with the assertion by Ljajko & Ibro (2013) who stated that GeoGebra can help with the learning process efficiency and encourage students to be more active in participating in the learning process. GeoGebra helps students visualize mathematical objects, making it easier for them to understand the material. This is aligned with Fitriyani & Sugiman (2014) who stated that GeoGebra is better at producing more dynamic visualizations in geometry than some other types of software. The combination of the MMP learning model and GeoGebra software makes mathematics learning more varied, enjoyable, and motivating, and it makes students active in the learning process, resulting in more meaningful learning for students.

CONCLUSION

The study demonstrates that the implementation of the GeoGebra-assisted MMP learning model positively impacts the mathematical communication abilities of students, as evidenced by higher posttest scores in the experimental class compared to the control class. Additionally, the effect size analysis indicates a moderate effect of the GeoGebra-assisted MMP learning model on students' mathematical communication abilities, further supporting its effectiveness in enhancing this skill. Consequently, teachers are encouraged to integrate the GeoGebra-assisted MMP learning model into their mathematics classes to improve students' proficiency in mathematical communication, emphasizing the importance of thorough lesson planning to optimize the learning process. Moreover, the study suggests several recommendations for future endeavors. Firstly, teachers should continue utilizing the MMP learning model with GeoGebra assistance in their classrooms to foster students' mathematical communication abilities. Additionally, researchers are encouraged to conduct similar studies to address potential limitations and expand upon the findings, thereby contributing to the body of knowledge and providing valuable insights for the improvement of teaching practices and student learning outcomes in mathematics education.

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