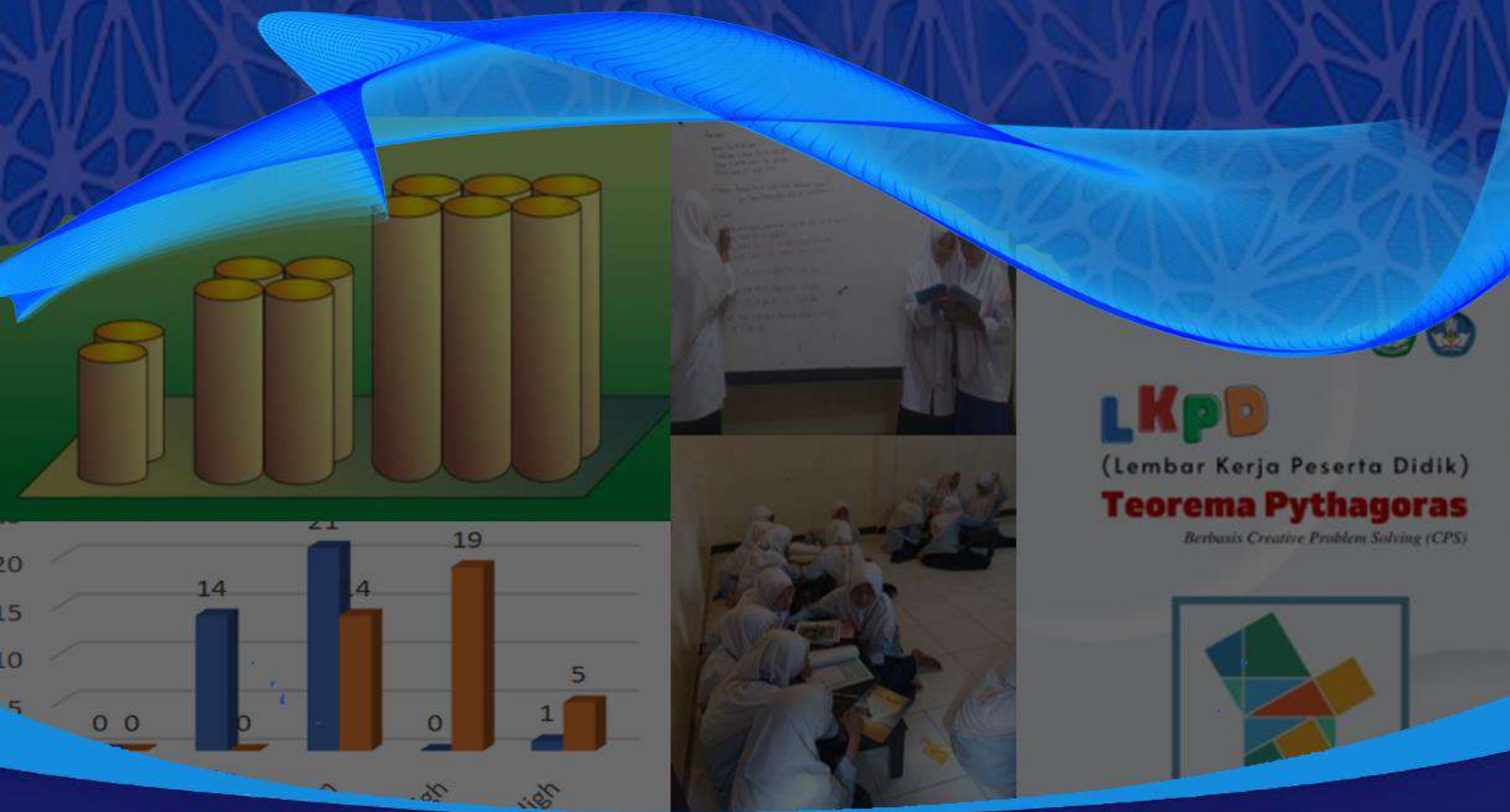


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Preface

Assalamu 'alaikum wr.wb.

Dear readers of the Jurnal Kreano,

Kreano, Jurnal Matematika Kreatif-Inovatif, Vol. 15 (2), December 2024 is here to greet loyal readers, academics who have a young spirit in serving, storing, criticizing, and providing solutions to every phenomenon that occurs in learning mathematics through steps the scientific.

Technology's role in mathematics education emerges prominently, with research examining mobile technologies, Google Sites, Mathigon, and ChatGPT as virtual tutors. These tools aim to strengthen students' communication and conceptual understanding, particularly in complex topics such as linear equations, integers, and trigonometric ratios. Additionally, the exploration of unique learning methods for students with mild intellectual disabilities, the development of creative problem-solving frameworks, and strategies for addressing learning obstacles further underscore the field's commitment to inclusive and effective pedagogy. By leveraging context, creativity, and technology, these studies collectively contribute to advancing educational practices and fostering comprehensive skill development in students.

Hopefully the Journal together with authors, researchers, and readers can be part of the process of improving the quality of education.

Happy reading!

Wassalamu 'alaikum wr.wb.

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Table of Content

| | |
|--|---------|
| Title | i |
| Editorial | iii |
| Preface | v |
| Table of Content | vii |
| | |
| 25. What kind of Relation and Function Worksheet Based Tri-N improve Critical Thinking Skills?, by Dr. Sri Adi Widodo, M.Pd., Ika Wulandari, Annis Deshinta Ayuningtyas, Dr. Widowati Pusporini, S.Si., M.Pd., Dr. Dianne Amor Kusuma, M.Pd., Estiyan Dwipriyoko | 342-362 |
| 26. Analysis of Errors in Students' Mathematical Communication Skills Based on Kastolan Stages at Ban Eyoh School, Thailand, by Sri Wahyuni Lubis, Fitriani, Ainun Mardiyah Lubis, Yulia Anita Siregar, Sakinah Samoh | 363-374 |
| 27. Effectiveness of TikTok-assisted Learning Supplement to Improve Students' Concept Understanding Ability and Learning Interest, by Muhammad Azril Rizky Maulana, Depi Setiaesmana, S.Pd., M.Pd., Dr. Eko Yulianto., S.Pd., M.Pd. | 375-394 |
| 28. Development of Islamic boarding school-based learning tools on social arithmetic material to improve students' numeracy skills, by Ahmad Anas Habibi, Dr. Nurcholif Diah Sri Lestari, M.Pd., Dr. Dian Kurniati, S.Pd., M.Pd., Dr. Susanto, M.Pd., Dr. Erfan Yudianto, S.Pd., M.Pd., Ihsan Sanawi | 395-408 |
| 29. Analysis of Students' Mathematical Concept Understanding Ability in Terms of Student Resilience at Ban Kadeng School Thailand, by Lisa Khairani Lubis, Ainun Mardiyah Lubis, Fitriani, Yulia Anita Siregar, Abdullah Jehnah | 409-422 |
| 30. Analogical Reasoning of Sensing and Intuition Personality Student in Solving Proportion Problem: Two-Variable into Three-Variable Direct Proportion Word Problem, by Dr. Suwarno, S.Pd, M.Pd., M. Aditiya Silvatama, Joel I. Alvarez, Wasilatul Murtafiah | 423-437 |
| 31. Problem Solving in Geometry Teaching for Pre-service Mathematics Teacher Students from a Computational Thinking Perspective, by Prof. Al Jupri, S.Pd., M.Sc., Ph.D., Dr. Dian Usdiyana, M.Si., Dr. Sumanang Muhtar Gozali, M.Si. | 438-449 |
| 32. Exploration of Mathematical Communication Skills of Students with Mild Intellectual Disability Through Manipulative Activities Using Bowls and Marbles, by Arif Muchyidin, Prof. Dr. Nanang Priatna, M.Pd., Prof. Dr. Nurjanah, M.Pd. | 450-462 |
| 33. Development of Pythagorean Theorem Content Worksheets Based on Creative Problem Solving to Facilitate Mathematical Reasoning Skills, by Dr. Elfis Suanto, M.Si., Efni Rianti, Dra. Armis, M.Pd, Assoc. Prof. Dr. Hutkemri Zulnaidi | 463-480 |
| 34. Development of a Local Instruction Theory for Trigonometric Ratios, by Dini Andiani, Dr. Elah Nurlaelah, M.Si, Prof. Dr. H. Darhim, M.Si | 481-500 |
| 35. The Role and Evaluation of ChatGPT as a Virtual Tutor in Improving Students' Creative and Critical Abilities Reviewed from Probing-Prompting Abilities, by Syahrul Zein, Prof. Dr. R. Poppy Yaniawati, M.Pd., Dr. Achmad Mudrikah, M.Pd. | 501-517 |
| 36. Technology Integration in Learning Design to Improve PGMI Students' Mathematical Communication Skills on the Concept of Integers, by Suharti, Prof. Dr. Usman Mulbar, M.Pd., Drs. Ahmad Talib, M.Si., Ph.D. | 518-527 |
| 37. Exploring the Use of Mobile Technologies in Indonesian Mathematics Lectures, by Dr. Muhamad Galang Isnawan, M.Pd., Dr. Naif Mastoor Alsulami, Dr. Sudirman, M.Pd., Wanda Nugroho Yanuarto, M.Pd., Prof. Dr. Drs. I Ketut Sukarma, M.Pd | 528-547 |

| | |
|--|---------|
| 38. Interrelationship of Mathematical Problem-Solving Ability, Mathematical Disposition, and Gender among Grade 10 Students, by Dr. Alimuddin, M.Si., Dr. Hisyam Ihsan, M.Si., Ofra Maylin Sulleng, S.Pd., M.Pd. | 548-565 |
| 39. Students' Geometric Creative Thinking Skills: An Analytical Study, by Dr. Endang Istikomah, M.Ed., Dr. Suripah, S.Pd, M.Pd., Abdurrahman, S.Pd., M.Pd., Cindy Hanema Dwi Putri | 566-577 |
| 40. Developing Google Sites and Mathigon Learning Media to Support Students' Conceptual Understanding in Solving Linear Equations in One Variable, by Dhea Puspita Putri Agustin, Maria Suci Apriani, S.Pd., M.Sc., Melania Liliastri Sali | 578-592 |
| 41. Students' Learning Obstacles in Solving Mathematical Proficiency Tasks: A Hermeneutic Phenomenological Study Focused on Algebra, by Dilham Fardian, Prof. Dr. Didi Suryadi, M.Ed, Prof. Dr. Sufyani Prabawanto, M.Ed | 593-618 |
| Author Index | xi |
| Manuscript Template..... | xiii |
| Subscription Page | xvii |



What kind of Relation and Function Worksheet Based Tri-N improve Critical Thinking Skills?

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Abstract

Mathematical critical thinking skills have so far shown unsatisfactory results, so media or learning resources such as worksheets are needed to complete them. In addition, concepts of scientific learning such as Niteni, Nirokke, and Nambahi activities have not provided opportunities for students to think critically. For this reason, this study aims to obtain valid and practical relations and function worksheets based on tri-n. The research stages used are defining, designing, and developing. These three stages are part of the development research with 4D. At the defining stage, data collection techniques use documentation to make the data analysis qualitative. At the design stage, data collection techniques use observation to make the data analysis qualitative descriptive. In the developing stage, the data collection technique uses a questionnaire, so the data analysis is quantitative. The results showed that the relations and function worksheets based on Tri-N had a V-Aiken index of more than 0.83, and some students responded well to this worksheet. Apart from that, the mathematics material in this Student Worksheet uses the Tri-N stages, namely Niteni, Nirokke, and Nambahi. Based on this, it can be concluded that the Tri-N-based Student Worksheet on Relations and Functions is a valid and practical result of development. For this reason, this worksheet can be used to improve students' critical thinking skills.

Keywords: Critical Thinking; Niteni; Nirokke; Nambahi; Worksheet.

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Abstrak

Kemampuan berpikir kritis matematis siswa selama ini menunjukkan hasil yang belum memuaskan, sehingga dibutuhkan media atau sumber belajar seperti worksheet untuk menyelesaikannya. Selain itu, konsep pembelajaran saintifik seperti kegiatan *Niteni*, *Nirokke*, *Nambahi* belum memberikan kesempatan kepada siswa untuk berpikir kritis. Untuk itu penelitian ini bertujuan untuk memperoleh Lembar Kerja Siswa Relasi dan Fungsi berbasis Tri-N yang valid dan praktis. Tahapan penelitian yang digunakan adalah mendefinisi, mendesain, dan mengembangkan. Ketiga tahapan ini merupakan bagian dari penelitian pengembangan tipe 4D. pada tahap mendefinisi, Teknik pengumpulan data menggunakan dokumentasi, sehingga analisis data yang digunakan bersifat kualitatif. Pada tahap mendesain, Teknik pengumpulan data menggunakan observasi, sehingga analisis data yang digunakan bersifat kualitatif deskriptif. Tahap mengembangkan, Teknik pengumpulan data menggunakan angket, sehingga analisis data yang digunakan bersifat kuantitatif. Hasil penelitian diperoleh bahwa Lembar Kerja Siswa Relasi dan Fungsi memiliki indeks *V* Aiken lebih dari 0,83, dan sebagian siswa memberikan respon sangat baik terhadap prototipe worksheet ini. Selain itu, materi matematika yang ada pada Lembar Kerja Siswa ini menggunakan tahapan Tri-N, yaitu *Niteni*, *Nirokke*, dan *Nambahi*. Berdasarkan hal tersebut dapat disimpulkan bahwa Lembar Kerja Siswa Relasi dan Fungsi berbasis Tri-N hasil pengembangan yang valid dan praktis. Untuk itu dimungkinkan worksheet ini digunakan sebagai salah satu cara untuk meningkatkan kemampuan berpikir kritis siswa.

INTRODUCTION

Mathematics education contains many connections with real life, presented verbally and visually with pictures, photos, diagrams and other visualizations. The context is drawn from a broad spectrum of real-life areas, reflecting that mathematics can be found everywhere in society (Wijers & de Haan, 2020). However, mathematics is a complicated subject, a whole of formulas and numbers. Students also think that mathematics is unrelated to everyday life, so students' interest in learning mathematics is often in the low category (Pratama et al., 2018) even though mathematics is an important subject that needs to be studied because it underlies other subjects and plays an essential role in all aspects of life, especially in improving human thinking power (Indiyah et al., 2021).

The teachings of *Niteni*, *Nirokke*, and *Nambahi*, often referred to as Tri-N, are Tamansiswa teachings that originate from the thoughts of Ki Hadjar Dewantara (Ardhyantama, 2020; Nisa et al., 2019). The concept of the Tri-N approach is in line with the scientific approach, where this learning provides opportunities for students to actively observe, ask questions, collect data, as well as associate and

communicate (Anafiah & Hangestiningih, 2019; Istiqomah et al., 2021; Wijayanti, 2018). In contrast to APOS, which emphasizes the knowledge framework formed from a person's cognitive processes starting from interiorization, coordination/retrieval, and encapsulation/de-encapsulation so that the schema always remains in everyone (Firdaus et al., 2023; Irfan et al., 2020), Tri-N places more emphasis on the syntax of learning that must be passed through, in the learning process (Ermawati & Rochmiyati, 2020).

Niteni is a student activity that is characterized by careful use of the five senses, where through this observation, detailed/specific and in-depth information is obtained and linked to students' prior knowledge (Damayanti & Rochmiyati, 2019; Istiqomah et al., 2021). *Niteni* is a cognitive process or human mind derived from the word "*titen*" (Nisa et al., 2019; Wijayanti et al., 2022). *Niteni* or *titen* refers to the ability to carefully recognize and capture the meaning (nature, characteristics, procedures, truth) of an object being observed by paying attention, comparing, scanning, observant and deep and involving all the senses (Nisa et al., 2019).

Nirokke, or imitating, is the nature of childhood. Behavior imitates models or

examples from teachers or learning resources (Rochmiyati & Putro, 2020; Wijayanti et al., 2021). *Nambahi* is or is a continuation of the *Nirokke* (Andayani et al., 2021). In this process, there is a creative and innovative process to give new colours to the imitating model. *Nirokke* is very useful for students because it has the nature of self-education through orientation and experience (Nita et al., 2017). *Nirokke* is not wrong, but duplicating or imitating models, methods, enthusiasm, and management is helpful for students to absorb the information provided by the teacher (Wijayanti & Utaminingsih, 2017). Learning *Nirokké* can be done by modelling or copying other people's behaviour (teachers, friends, society, etc.) to develop knowledge and learning experiences.

Nambahi means adding or can be translated as imitating by developing (Sibyan et al., 2019). The *Nambahi* activity is a follow-up activity after *Nirokke*. This *Nambahi* activity is expected to happen to students, so they do not just imitate or duplicate the information the teacher has received. So, in acquiring new knowledge, students do not just imitate the information provided by the teacher but also must process the information they obtain. In the *Nambahi* process, of course, there is a creative and innovative process to provide new nuances to the model being imitated (Herawati, 2019; Rozak & Wardina, 2014) so that we do not just imitate but improve, add, reduce, change and process something that is replicated.

The results of previous research show that implementing the Tri N concept can foster a creative spirit, build an attitude of honesty, discipline, hard work, creativity, independence, and curiosity, and develop abilities in participants (Nisa et al., 2019; Novika & Harahap, 2018). This concept can be viewed as a learning theory (Nita et al., 2017). The Tri-N concept

from Ki Hajar Dewantara can also be said to be a technique in learning (Rozak & Wardina, 2014). These studies show that Tri-N affects the learning outcomes that students must have. Besides that, many studies have implemented the Tri-N concept in mathematics learning. Such as learning Integral material using Tri-N and YouTube media (Wigati et al., 2018) and improving learning outcomes in junior high school of Muhammadiyah 2 Depok class IX students in 2019/2020 using the Tri-N concept assisted by structured worksheets on number material (Widada, 2020). Jigsaw Learning with Tri-N will increase mathematics activity and learning outcomes in class VII students at junior high school in Banguntapan (Pramudya & Harini, 2020). This shows that Tri-N can be used as an alternative to learning mathematics. Even though the tri-N learning that has been carried out cannot stand alone, it must involve other aspects such as learning models, learning media, teaching materials and worksheets (Ermawati & Rochmiyati, 2020; Holis, 2017; Pramudya & Harini, 2020; Wijayanti et al., 2021).

The worksheet is a student guide used to carry out investigative and problem solving activities and contains activities that students must carry out (Hayati et al., 2016; Prabawati et al., 2019; Purwasi & Fitriyana, 2019). This causes worksheets to be seen as learning media and a learning resource (Astuti et al., 2017; Priyambodo et al., 2012). Both as a medium and as a learning resource, the ultimate goal of the worksheet is to assist students in maximizing their understanding and abilities through the learning achievements that must be taken.

Many researchers have carried out research related to worksheets with student abilities. Such as the effect of the worksheet on the ability to solve problems (Ichsan et al., 2023; Widodo et al.,

2023), the impact of the worksheet on the ability to think creatively (Aripin & Purwasih, 2017; Islamiyati et al., 2023; Purwaningsih et al., 2021), worksheet effect on mathematical communication skills (Ismail et al., 2020; Riyati & Suparman, 2019), the impact of worksheets on critical thinking skills (Fernando et al., 2021; Hayati et al., 2016; Ningrum et al., 2022). The results of this study indicate that worksheets have a potential effect on improving students' abilities. However, the study results show that students' soft and hard skills are still not optimal. As previously reported, students' critical thinking skills are still low (Agnafia, 2019; Nuryanti et al., 2018; Priyadi et al., 2018). At the same time, thinking critically is thinking logically and systematically when deciding or solving a particular problem (Murni et al., 2022; Nuryanti et al., 2018; Wulan-sari et al., 2019). For this reason, it is necessary that worksheets can be used as an alternative media or learning resource so that students' cognitive abilities, such as students' mathematical critical thinking skills, can increase.

In this regard, the objectives to be achieved from this research include finding out the validity, practicality and effectiveness of Tri-N based worksheets on relations and functions to improve the critical thinking skills of junior high school students. The material for relations and functions was chosen in the development of this worksheet because this material is one of the subject matters of mathematics studied by students in grade VIII of junior high school and one of the basic materials for entering the following material such as limits of functions, derivatives and others (Lesiana & Hiltrimartin, 2020; Melani & Sutirna, 2020; Septianti, 2020). In addition, the results of the preliminary study conducted earlier found that the ability of junior high school students to understand the material on relations and

functions stated that students still lacked mastery of the problems faced. Most students considered the questions to be difficult, students were less enthusiastic about understanding the questions, and students also felt confused about solving the questions given (Anggraini et al., 2021; Martha & Reni, 2022; Pendy & Mbagho, 2021).

METHOD

In accordance with the objectives of this research, the stages of this research are defined, designed, developed, and disseminated (Thiagarajan et al., 1974). Four steps on 4D are divided into nine main activities: curriculum analysis, Tri-N analysis, Analysis of critical thinking skills, learning objective, prototype of worksheet, validation Expert, development testing, validation testing, packaging, diffusion and adoption (see Figure 1).

The define stage is carried out to determine, define and analyze the needs of the product to be developed (Thiagarajan et al., 1974). The product to be designed in this research is the Relation and Function Worksheet Based Tri-N. The needs analysis includes (1) curriculum analysis, (2) Tri-N analysis, and (3) analysis of critical thinking skills. For this reason, at this early stage, the researcher did not test the hypothesis but focused on the development needs analysis activities and the requirements for product development according to user needs (in this case, the needs of teachers and students in junior high school).

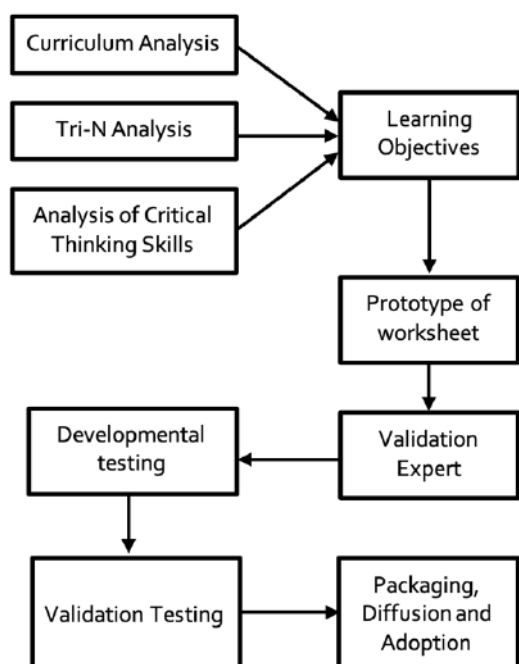


Figure 1. Research Stages

At the design stage, a product development format is developed (Thiagarajan et al., 1974). It is intended that the initial design of the product in the form of a Relation and Function Worksheet Based on Tri-N has an overview. At this stage, it is expected to have an effect as a Relation and Function Worksheet Based Tri-N prototype.

The development stage consists of two things that must be done: expert validation and developmental testing (Thiagarajan et al., 1974). At the expert validation stage, it is carried out to determine the quality of the prototype of relation and function worksheet based Tri-N that has been designed based on aspects (a) design and layout of the worksheet, (b) mathematical content, (c) Tri-N content, and (d) language. Developmental testing activities are carried out to determine student responses to the relation and function worksheet prototype based on Tri-N to increase students' critical thinking skills. Trials of prototype relation and function worksheet based tri-N given to class 8 students of Junior High School. The results obtained in this trial were in the

form of student responses received from filling out a questionnaire conducted by students.

The last stage, or dissemination stage, aims to promote the product developed to be accepted by individual users. The dissemination stage has three main steps: validation testing, packaging, diffusion, and adoption (Thiagarajan et al., 1974). In the validation testing stage, the product revised at the development stage is implemented on the actual target or target. This activity aims to determine the effectiveness of the product being developed; in this case, the product's effectiveness is seen from the students' critical thinking abilities. The packaging stage is carried out by printing a worksheet. This worksheet is published so that others can diffuse and adopt the product.

The data collection method in this study was adapted to the stages of the research. The define stage is done with documentation. The documentation at this stage is in the form of a *Merdeka* curriculum policy such as Minister of Education, Culture, Research and Technology Regulation No. 262/M/2022, and Decree of the Head of Education Standardization, Curriculum and Assessment Agency Number 033/H/KR/2022. In addition, other documentation, such as study results published by researchers and accessed online, is also used at the define stage. At the design stage, data collection was carried out using observation. Researchers are designing prototype products of relation and function worksheets based on Tri-N.

At the development stage, data collection techniques are carried out by means of a questionnaire. The questionnaire used at this stage is a validation sheet that experts must fill out. This questionnaire evaluates the prototype of the Relation and Function Worksheet Based Tri-N designed in the previous step. Vali-

dation questionnaires were given to experts, in this case, practitioners and academics. Practitioners used as experts at the validation stage were junior high school mathematics teachers, while the academics used as experts in the validation stage were lecturers in mathematics education. In addition to the validation questionnaire, a student response questionnaire was used to operate the prototype relation and function worksheet based on Tri-N. This response is used to see the readability of the worksheet designed in the previous stage.

At the dissemination stage, data collection techniques are carried out by means of tests. This test is used to determine students' critical thinking abilities. The critical thinking ability test assessment indicators refer to the scoring rubric from Ismaimuza (2013), Facione (1992),

Rosliani & Munandar (2022), and Kurniasih et al. (2020), namely Interpretation, Analysis, Evaluation and inference. More details can be seen in Table 1.

Qualitative descriptive data analysis techniques were used for the define and design stages. Data analysis techniques using descriptive qualitative methods are carried out by 1) preparing and organizing data for analysis, (2) exploring and coding data, (3) coding to build descriptions, (4) representing and reporting findings, (5) interpreting results, and (6) validate the accuracy of the findings (Creswell, 2012).

At the development stage, quantitative data analysis is carried out. The data obtained from the validator is then analyzed using the Aikens Formula (Aiken, 1980, 1999; Aiken & Patrician, 2000), as follows:

Table 1. Mathematical thinking ability assessment rubric

| INDICATOR | INFORMATION | SCORE |
|----------------|--|-------|
| Interpretation | Students do not write down what is known and what is asked | 0 |
| | Students write down what they know and what they ask, but it is not quite right | 1 |
| | Students write only what is known or what is asked | 2 |
| | Students write down what they know from the question, but it is not quite right | 3 |
| | Students write and ask questions ultimately and accurately | 4 |
| Analysis | Students do not create mathematical models from the problems given | 0 |
| | Students make mathematical models from the questions given, but they are not quite right | 1 |
| | Students create mathematical models from the questions given correctly without providing explanations | 2 |
| | Students create mathematical models from the questions given correctly, but there are errors in the explanation | 3 |
| Evaluation | Students create mathematical models of the questions given correctly and provide correct and complete explanations | 4 |
| | Students do not use strategies to solve problems | 0 |
| | Students use incomplete and inappropriate strategies in solving problems | 1 |
| | Students use strategies in solving problems that are incomplete or use strategies that are incomplete but complete in solving problems | 2 |
| Inference | Students use appropriate and complete strategies in solving problems but make errors in calculations or explanations | 3 |
| | Students use appropriate, complete and correct strategies in solving problems | 4 |
| | Students do not make conclusions | 0 |
| | Students make conclusions, but they are inaccurate and not appropriate to the context of the problem | 1 |
| | Students make conclusions, but they are not correct even though they fit the context of the question | 2 |
| | Students make conclusions correctly, according to the context of the question, but are not complete | 3 |
| | Students make conclusions wholly and correctly according to the context of the problem | 4 |

$$eV = \frac{\sum s}{n(c-1)}$$

With,

eV = rater agreement index

n = the number of raters

S = the score set by each rater minus the lowest score in the category used ($r - l_0$)

l_0 = lowest validity rating score

c = the highest validity rating score

r = the number is given by the validator

This formula determines how far the Tri-N Based Relation and Function Worksheet prototype is valid. The rater agreement index statistically ranges from 0 to 1. The number of raters (in this case, the appraisers) used in this study was six people. The validity criteria were determined from the validity index obtained and then compared with the Aiken V Index table. For the number of raters 6 in Table V Aiken received 0.78 (Aiken 1985). For this reason, a product is said to be valid for each item if the Aiken V Index is calculated to be more than 0.78.

The data obtained from student responses is collected by looking at the percentage of answers given by students for each aspect of the total number of students. Student response to the prototype product relation and function worksheet based Tri-N refers to the Likert scale, namely efficient with a score of 5, practical with a score of 4, less practical with a score of 2, and impractical with a score of 1. Furthermore, the results of the percentage of student responses obtained for each indicator, the average is determined and grouped into very practical, practical, less practical, and impractical, as can be seen in Table 2 (Afifah et al., 2021; Ikram et al., 2021).

Table 2. Practical level category

| No | Percentage (P) | Category |
|----|----------------------|----------------|
| 1 | $75 \leq P \leq 100$ | very practical |
| 2 | $50 \leq P < 75,0$ | practical |
| 3 | $25 \leq P < 50$ | Less practical |
| 4 | $0 \leq P < 25,0$ | impractical |

The results of this percentage indicate the practicality of a product resulting from its development (Ardianti et al., 2019; Annisa et al., 2022). Where the prototype relation and function worksheet based on Tri-N is considered practical, at least 50% of students say it is very practical.

At the dissemination stage, data is obtained at the validation testing stage. Because, at this stage, the aim is to determine the effectiveness of the LKPD product in terms of students' critical thinking abilities, data on this ability was obtained from the pre-test and post-test. To see its effectiveness, data analysis uses N-Gain (Aziz et al., 2021; Hake, 1998), namely

$$N - Gain = \frac{Post\ test\ Score - Pre\ tes\ Score}{Ideal\ Score - Pre\ tes\ Score}$$

Analysis carried out on the results of the interpretation of the N-gain value criteria (Hake, 1998; Trisniawati et al., 2019) is shown in Table 3.

Table 3. N-Gain Score Interpretation

| Score | Interpretation |
|--------------------------------|----------------|
| $N - Gain < 0.30$ | Low |
| $0.30 \leq N - Gain \leq 0.70$ | Medium |
| $N - Gain > 0.70$ | High |

The effect size e-Worksheet uses Cohen's d formulation (Goulet-Pelletier & Cousineau, 2018; Lakens, 2013; Maher et al., 2013) as follows:

$$ES = \frac{M_{diff}}{\sqrt{\frac{\sum (X_{diff} - M_{diff})^2}{N - 1}}}$$

With,

ES = effect size

M_{diff} = the mean of the difference between post-test and pre-test data

X_{diff} = difference between posttest and pretest data

N = sample size

Analysis of the results of the interpretation of the effect size criteria (Cohen et al., 2007; Yunita et al., 2021) is presented in Table 4.

Table 4. Effect Size Interpretation

| Effect Size | Interpretation |
|-----------------------|----------------|
| $0.00 \leq ES < 0.20$ | Ignored |
| $0.20 \leq ES < 0.50$ | Small |
| $0.50 \leq ES < 0.80$ | Fair |
| $0.80 \leq ES < 1.30$ | Large |
| $ES \geq 1.30$ | Very large |

RESULT AND DISCUSSION

Results

The stages carried out in this study are defining, designing, developing, and disseminating. The results of this study for each stage are presented in the following explanation.

Define

In the define stage, it is carried out to analyze needs related to (1) curriculum analysis, (2) Tri-N analysis, and (3) analysis of critical thinking skills. At this stage, it is not carried out to test a hypothesis, but it is focused on needs analysis activities and product development requirements tailored to user needs (Thiagarajan et al., 1974).

Curriculum analysis is done by dissecting learning outcomes in the independent Relation and Function material curriculum. This curriculum review is carried out to determine the suitable material about relations and function. A decree number 033/H/KR/2022 issued by Agency of Standardization, Curriculum, and Assessment of Education (*Badan Standardisasi, Kurikulum, dan Asesmen Pendidikan*) found that the Relation and Function material included in the algebraic elements with the learning outcomes being students can understand relations and func-

tions (domain, codomain, range) and present it in the form of arrow diagrams, tables, sets of ordered pairs, and graphs. From the learning outcomes of this study, the material on relations and functions consists of relationships, functions, and mappings; the characteristics of relations and functions; formulas of functions; graphs of functions; and problem-solving related to relations of function.

Tri-N is a learning activity that aligns with the scientific approach, using the *niteni*, *nirokke*, and *nambahi* stages (Damayanti & Rochmiyati, 2019; Wigati et al., 2018). The Tri-N analysis is carried out by reviewing published articles that can be accessed through Google Scholar. The results of the review of published articles obtained indicators for the stages of Tri-N. *Niteni* is an activity that involves marking by paying close attention and using all the senses (Damayanti & Rochmiyati, 2019). In this *niteni* activity, it is also a process of seeking and finding meaning (nature, characteristics, procedures, truth) of an object of safety from the five senses (Wijayanti et al., 2021; Wijayanti et al., 2023). *Niteni* activities can include listening to teacher explanations and conducting literature reviews by identifying reading content through the 5W + 1H formula (Anafiah & Hangestingsih, 2019).

Nirokke is an activity of imitating what is taught through models/examples/examples from teachers/learning resources by involving the mind, senses, feelings/conscience, and spirituality integrally and harmoniously (Ermawati & Rochmiyati, 2020; Rochmiyati & Putro, 2020). *Nambahi* adds or subtracts what he has learned to develop his creativity and ideas by utilizing learning resources (Hidayati & Khasanah, 2020; Rochmiyati & Putro, 2020).

Critical thinking skills analysis shows

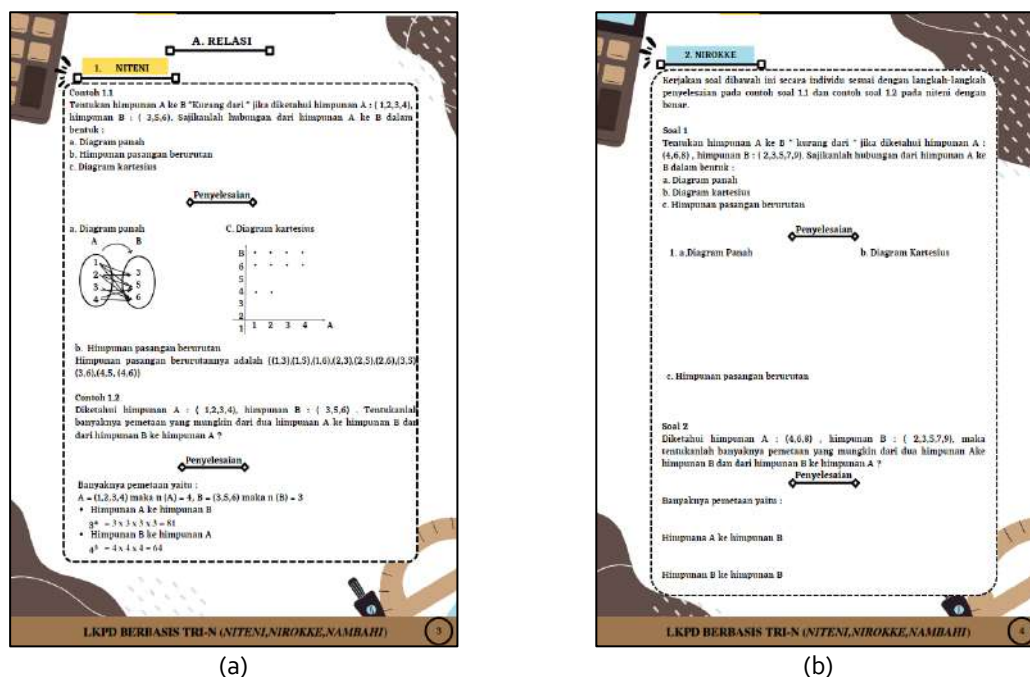


Figure 2. Display of Relation and Function worksheet based Tri-N

that this ability's indicators include interpretation, analysis, inference, explanation, and self-regulation (Agnafia, 2019; Rositawati, 2019; Ariq & Fitrihidajati, 2021). However, some research results suggest that indicators of mathematical critical thinking ability include (1) the ability to give reasons for mastering concepts and justifying concepts, (2) the ability to complete supporting data or information, and (3) the ability to evaluate or examine an algorithm (Buhaerah, 2016; Rahmasantika & Charitas, 2022; Zetriuslita et al., 2016). In addition, several research results have shown that mathematical worksheets affect or influence students' mathematical critical thinking skills. Therefore, if students' critical thinking skills are not optimal, one way to improve this ability is to use a mathematical worksheet.

Design

Learning outcomes have been determined on relations and functions at the defined stage. These learning outcomes refer to decisions of the head of the Agency of Standardization, Curriculum,

and Assessment of Education number 033/H/KR to design a mathematical worksheet on Refunctionnd Functiowill be designed n material to improve junior high school students' critical thinking skills. The design of this mathematical worksheet aims to improve junior high school students' critical thinking skills so that one of the elements of the Pancasila student profile, namely critical reasoning, can be achieved. For this reason, the design of this mathematical worksheet includes mathematical problems that can stimulate students to think critically. Several views of relations and Functions worksheet based Tri-N can be seen in Figure 2.

Develop

Two activities are carried out at the development stage: expert validation and developmental testing (Thiagarajan et al., 1974). The goal of these two stages is to see the validity of the Relation and Function product prototype worksheet bai-N in theoretical and empirical terms. Thus, the prototype relation and Function worksheet based on Tri-N could be a hypothetical product ready to be tested on a large

scale.

The validation expert activity involved three mathematics education lecturers and three junior high school mathematics teachers. Their involvement at this stage is to become a validator whose job is to provide assessments, suggestions, and criticism product of the Relation and Function worksheet based on Tri-N. The Tri-N worksheet based Relation and Function product assessment refers to indicators (1) design and Layout, (2) mathematical content, (3) Tri-N content, and (4) language.

In the design and layout indicators, it consists of 6 sub-indicators, namely (1) initial appearance (cover), (2) font type and font size, (3) figure, (4) colour and appearance, (5) the attractiveness of the worksheet, and (6) the identity of the author. The validation results on this indicator can be seen in Table 5.

Table 5. Feasibility Assessment Results on Design and Layout Aspects

| No | Indicators | eV | Conclusion |
|----|-------------------------------------|------|------------|
| 1 | initial appearance (Cover) | 1,00 | Valid |
| 2 | font type and font size | 0,94 | Valid |
| 3 | figure | 0,83 | Valid |
| 4 | colour and appearance | 0,83 | Valid |
| 5 | the attractiveness of the worksheet | 1,00 | Valid |
| 6 | identity of the author | 1,00 | Valid |

Based on Table 5, it can be concluded that the prototype of the Mathematical Worksheet on the relation and function is valid for indicator design and layout. This is because all the items asked for in the design and layout indicators have an Aiken validity index of more than 0.78.

In the mathematical content indicator, it consists of 7 sub-indicators, namely (1) suitability of the material with learning outcomes, (2) suitability of the material with practice questions, (3) completeness

of the material, (4) suitability of learning objectives and activities, (5) material presentation system, (6) worksheets facilitate students to think critically, and (7) use of media. The validation results on this indicator can be seen in Table 6.

Table 6. Feasibility Assessment Results on Design and Layout Aspects

| No | Indicators | eV | Conclusion |
|----|---|------|------------|
| 1 | Suitability of the material with learning outcomes | 0,94 | Valid |
| 2 | Suitability of the material with practice questions | 1,00 | Valid |
| 3 | Completeness of the material | 1,00 | Valid |
| 4 | Suitability of learning objectives and activities | 0,83 | Valid |
| 5 | material presentation system | 0,94 | Valid |
| 6 | Worksheets facilitate students to think critically | 0,94 | Valid |
| 7 | Use of media | 0,83 | Valid |

Based on Table 6, it can be concluded that the prototype of Mathematical Worksheet Relation and Function is valid for indicator mathematical content. This is because all the items asked for in the mathematical content indicator have an Aiken validity index of more than 0.78.

The Tri-N content indicator consists of 4 sub-indicators, namely (1) the initial display shows Tri-N, (2) the worksheet contains the Tri-N stages, (3) Materials and learning activities according to the tri-N stages, and (4) the worksheet invites students to do the Tri-N stages. The validation results on this indicator can be seen in Table 7.

Table 7. Results of the Feasibility Assessment on the Aspect of Tri-N Content

| No | Indicators | eV | Conclusion |
|----|---|------|------------|
| 1 | The initial display shows Tri-N | 1,00 | Valid |
| 2 | The worksheet contains the Tri-N stages | 1,00 | Valid |
| 3 | Materials and learning activities according to the tri-N stages | 0,83 | Valid |

| No | Indicators | eV | Conclusion |
|----|---|------|------------|
| 4 | The worksheet invites students to do the Tri-N stages | 1,00 | Valid |

Based on Table 7, it can be concluded that the prototype mathematical Worksheet in material relation and function is valid for indicator Tri-N content. This is because all the items asked for in the Tri-N content indicator have an Aiken validity index of more than 0.78.

The language indicator consists of 2 sub-indicators, namely (1) use of language and (2) use of terms and symbols. The validation results on this indicator can be seen in Table 8.

Table 8. The results of the feasibility assessment on the language aspect

| No | Indicators | eV | Conclusion |
|----|--------------------------|------|------------|
| 1 | Use of language | 0,83 | Valid |
| 2 | use of terms and symbols | 0,83 | Valid |

Based on Table 8, it can be concluded that the prototype mathematical Worksheet in material relation and function is valid for indicator language. This is because all the items asked for in the indicator language have an Aiken validity index of more than 0.78.

In addition to conducting a quantitative assessment, the validators provide qualitative assessments. The qualitative assessment they carried out was in the form of giving criticism and suggestions related to relations and function worksheet based Tri-N. The summary of recommendations and criticisms on the product of relation and Function worksheet based on Tri-N provided by the validator can be seen in Table 9. From these suggestions and criticisms, the next researcher can determine the follow-up strategy that must be carried out to improve the relation and function worksheet based on Tri-N.

Relation and Function worksheet based Tri-N, which has been repaired based on suggestions from validators, then a limited scale trial (small trial) was conducted to 10 junior high school students selected purposively. This trial aims to obtain responses or student responses to relation and function worksheet based Tri-N. Reactions from students were received by giving questionnaires with indicators of worksheet display, presentation of material, student attractiveness and product usefulness. The worksheet display indicator consists of 3 statement

Table 9. Suggestions and Follow-Up Plans

| No | Suggestion | Follow-Up |
|----|--|---|
| 1 | In making an arrow diagram, it is better to write down sets of A and B; don't forget to write them because students will get confused. | The letters A and B are added to the arrow diagram to make it easier for students to get to know a set of A and a set of B. |
| 2 | In typing a rank number, it must be made like AB, not classified as A, to the power of B. | We are changing and retyping the correct way to type epaulettes in questions. |
| 3 | Determine the choice of words in making questions, and don't forget to always pay attention to writing so there are no typos. | Change the choice of words that have been suggested and be more careful in making questions so that there are no typos. |
| 4 | The arrangement of letters on the worksheet is given space | Change the order of notes on the worksheet so that there is room for students to write on the worksheet. |
| 5 | For pictures on the worksheet, you can colour them to make them more attractive, not just on the edges. | The images in the worksheet have been changed and coloured to make them more attractive to students. |
| 6 | In the subsequent development, to make the worksheet even better. | It was fixed in subsequent developments to make it more attractive. |

items, the material presentation indicator consists of 7 statements, the attractiveness indicator consists of 2 comments, and the product usability indicator consists of 3 statements. The results of these student responses can be seen in Table 10.

Table 10. Percentage of Small Trial Results to Student Responses

| No | Assessment Aspects | Percentage | | | |
|----|-----------------------|------------|-------|----|----|
| | | 5 | 4 | 2 | 1 |
| 1 | Appearance | 73,33 | 26,66 | -- | -- |
| 2 | Material Presentation | 57,14 | 42,85 | -- | -- |
| 3 | Attractiveness | 55,00 | 45,00 | -- | -- |
| 4 | Usefulness | 63,33 | 36,66 | -- | -- |
| | average | 62,20 | 37,80 | | |

Based on Table 10, the students' responses to relation and function worksheet based Tri-N obtained an average of 62.28 very agree and 37.79 very agree. For this reason, it can be concluded that in small-scale trials, the relation and function worksheet-based Tri-N has a positive response from students to improve their ability to think critically.

Disseminate

The three main activities that must be carried out at the dissemination stage are (1) validation testing, (2) packaging, and (3) diffusion and adoption (Thiagarajan et al., 1974). The validation testing activity aims to determine the effectiveness of the product being developed. In this case, the efficacy of the relation and function worksheet based on Tri-N is seen in the students' critical thinking abilities. At this stage, the research design uses a one-group pretest-posttest method with a sample size of as much as possible. Pretests and post-tests are carried out to obtain students' critical thinking skills. The description of critical thinking ability data can be seen in Table 11.

Table 11. Description of Pre-test, Post-test and N-Gain data on critical thinking skills

| Critical Thinking Skills | N | Interpretation | |
|--------------------------|----|----------------|----------|
| | | Mean | Variance |
| Pre-test | 28 | 20.68 | 46.89 |
| Posttest | 28 | 36.11 | 63.65 |
| N-Gain | 28 | 0.53 | 0.13 |

Based on the results of N-gain calculations, it was found that the average N-gain was 0.53 with a variance of 0.13 (see Table 11). These results show that the average N-Gain meets the medium criteria. Calculating the effect size using Cohen's formula also showed that the ES was 1.37. These results indicate that the effect size is at very large standards. From the results of the N-Gain and effect size calculations that have been carried out, it can be concluded that the product influences critical thinking skills in a very large category. This shows that the development of relation and function worksheet based Tri-N is effectively used in learning.

In the packaging, diffusion, and adoption stages, the Tri-N-based LKPD relations and functions are packaged in open access, which can be seen on Google Drive with the link <https://bit.ly/RelationFunctionWorksheet>. In the long term, this LKPD will be placed in <https://math-projekt.pmat.ustjogja.ac.id>. This aims to ensure that mathematics teachers are in phase D, and students or other researchers in the field of mathematics education can access this product easily.

Discussion

Worksheets are student guides for investigative or problem-solving activities (Hayati et al., 2016; Riyati & Suparman, 2019; Tsani et al., 2019). The worksheet contains a set of essential activities that students must carry out to maximize understanding and as a form of effort to improve critical thinking skills through the achievement of the learning outcomes

pursued (Wahyuningsih, 2019; Setiawati *et al.*, 2015; Roemintoyo & Budiarto, 2021). The components of the worksheet at least contain identity and cover, study instructions, learning competencies to be achieved or learning outcomes, learning achievement indicators, supporting information, tasks and work steps, assessments, and references or bibliography (Sakur *et al.*, 2023; Saraswati & Salsabila, 2021).

Worksheets are a learning resource that can be developed by teachers who act as facilitators in learning activities (Sugiarto & Hidayah, 2019; Widodo *et al.*, 2023). The worksheet development is expected to be used as a learning resource for students (Agustin *et al.*, 2019; Septian *et al.*, 2019) so that they get materials and directions indirectly from the teacher. Using worksheets, students are expected to experience a learning process in understanding the concepts being studied (Sumaryati & Husanah, 2015). Worksheets can be arranged and developed according to the conditions and situations of the learning activities (Listiani, 2018; Halija *et al.*, 2021). Worksheet based Tri-N use the stages of *nitenti*, *nirukke* and *nam-bahi*. These three Tri-N stages explicitly appear in the worksheet so that students can easily observe, imitate, and add to the knowledge they have received during their learning (Ardhyantama, 2020).

By the definition of a worksheet, namely a sheet that contains guidelines for students to carry out their learning activities, it is hoped that the use of worksheets in learning can measure the extent to which students can understand the material being studied. For Worksheet based Tri-N, students can use the learning materials and functions at the core learning activity stage. Core learning activities are the main activities in the learning process or the process of mastering students' learning experiences. These worksheets

can shape students' learning experiences and abilities as planned by the teacher, and students can observe, imitate and then add to the knowledge they have received.

Prototype assessment results of relation and function worksheet based Tri-N conducted by six validators obtained that the indicator design and Layout, mathematical content, Tri-N content, and language have a V-Aiken index of more than 0.83. Even though the Vaiken index for six validators is expected to have a V Aiken index of at least 0.73 (Aiken 1985), for this reason, it can be concluded that the prototype of relation and function worksheet based Tri-N is valid in terms of design and layout, mathematical content, Tri-N content, and language.

In addition, in a limited scale trial conducted on ten purposively selected junior high school students, it was found that most students stated that relation and function worksheet based Tri-N is very good in appearance, presentation of material, attractiveness, and usability.

The two interpretations obtained based on the validation results and the results of limited-scale trials show that the worksheet prototype developed is suitable for use in the following research stage: large-scale trials or the dissemination stage. Based on expert judgment, the worksheet obtained an Aiken index of more than 0.83, and some students responded very well to the worksheet prototype developed.

The results of this study indicate that the worksheet has the function of activating students in the learning process, mainly active in communication skills and involved in conveying opinions or ideas both in writing and verbally (Ika, 2018; Disanti & Rosdiana, 2019; Khikmiyah, 2021). In addition, the worksheet makes it easier for teachers to do learning. For stu-

dents, it is hoped that they can adapt independently to the material provided by the teacher (Irmeilyana et al., 2022).

By using a worksheet, it is suspected that students are more active in the learning process (Ginting & Ammy, 2022; Wewe & Bhoke, 2022), help in developing mathematical concepts (Effendi & Aini, 2018), practice discovering and developing process skills (Umbaryanti, 2016), as a guide for educators and students in carrying out the process of learning mathematics (Widada, 2016), The mathematical approach plays a vital role in helping students improve their abilities such as critical thinking skills (Rosita, 2014). This aligns with the results of other studies, which state that worksheets created using a mobile learning-based guided inquiry approach can theoretically optimize mathematical critical thinking skills (Sadiyyah et al., 2019). In addition, ethnomathematics-based worksheets with the STEM approach are effectively used to improve students' critical thinking skills (Novitasari et al., 2022). The results of developing worksheets based on discovery learning are valid, very practical and effective in learning mathematics to improve critical thinking skills (Murni et al., 2022).

The most striking difference between the current research and the research done so far is the worksheet approach used. In this study, the worksheet uses the approach of Tri-N and the material of relation and function. The relation and function worksheet contains straightforward content of the Tri-N Steps (*Niteni*, *Nirokke*, *Nambahi*) because every step is written in the worksheet. In contrast to previous research, such as worksheets with a guided inquiry approach based on mobile learning (Sadiyyah et al., 2019), ethnomathematics-based worksheets with a STEM approach (Novitasari et al., 2022), worksheets based on discovery

learning (Murni et al., 2022).

As is known, Tri-N is a learning stage (syntax) that must be passed during the learning process (Herawati, 2019; Nisa et al., 2019; Nita et al., 2017; Rozak & Wardina, 2014). As expressed by Ki Hajar Dewantara, Tri-N is not a thinking process but rather the stages of learning that children will carry out (Herawati, 2019; Rozak & Wardina, 2014). Tri-N consists of 3 stages: *Niteni*, *Nirokke*, and *Nambahi*. *Niteni*, taken from the Javanese language "titen", is a student activity carried out by paying attention, comparing, observing, being observant and in-depth, involving the five senses carefully, recognizing and capturing the meaning of an object (Damayanti & Rochmiyati, 2019; Istiqomah et al., 2021; Nisa et al., 2019; Novika & Harahap, 2018). So that students can obtain specific and in-depth information that is linked to students' prior knowledge. Students are expected to carry out the *Niteni* stage after carrying out the *Nirokke* stage. This second stage is the student's behaviour, which is to imitate the example given by the teacher or other learning sources (Rochmiyati & Putro, 2020; Wijayanti et al., 2021). *Nirokke* is very useful for students because it has the nature of self-education through orientation and experience (Sibyan et al., 2019; Wijayanti & Utaminingsih, 2017). Apart from that, the *Nirokke* stage is helpful for students to absorb the information provided by the teacher. The final stage of Tri-N is *Nambahi*. It is hoped that students will not only imitate or duplicate information received by the teachers expected to process the information they obtain (Herawati, 2019; Rozak & Wardina, 2014). They have creative and innovative abilities to give new colours to models or other imitated learning resources. The Tri-N stages in the worksheet cause students' critical thinking skills to be better when compared to using ordinary worksheets.

Implication of Research

In the prototype developed in this research in the form of a Tri-N based relations and function worksheet using the first three stages of 4D development research, it was found that the prototype worksheet was theoretical and empirical. Several implications are obtained based on this research, including that learning using Tri-N based worksheets on Relations and Function material can improve students' critical thinking skills on mathematics problems for junior high school students. This can be seen from the results of the N-Gain test and the effect size. For this reason, teachers in mathematics learning relationship and function material can consider using this research product to improve students' critical thinking skills.

Limitation

This research generally uses 4D development stages: define, design, develop and disseminate. The number of validators involved in assessing the product of Worksheet Tri-N is only six people, namely 3 (three) junior high school mathematics teachers and 3 (three) lecturers with a scientific background in mathematics education. However, there are no validators from lecturers who know mathematics learning technology. This is one of the weaknesses of this research.

Apart from that, at the product testing stage, an experiment was carried out to determine the effect of the development product (in this case, a Worksheet based Tri-N) on students' critical thinking skills on relationship and function material. However, the experiments did not compare the effects of worksheet based Tri-N and other worksheet models. For this reason, the results of this research can be considered to compare the effects of using worksheet based Tri-N with other

worksheet models on students' critical thinking skills.

CONCLUSION

Based on the results of research and discussion, it can be concluded that mathematical worksheet based Tri-N in material relation and function Improving the critical thinking skills of junior high school students has been successfully developed. Relation and function worksheet based Tri-N has theoretically and empirically fulfilled the feasibility test. Empirically, this worksheet obtained a Vaiken index of more than 0.78 for each assessment sub-indicator, so it can be declared valid. The results of students' responses to relation and function worksheet based Tri-N to improve the critical thinking skills of junior high school students obtained the result that 62.28% of students gave a very agree response and 37.79% of students gave a very agree response. From the students' responses, it can be concluded that relation and function worksheet-based Tri-N obtained positive responses (practical) from students to improve their critical thinking skills. Apart from the test results at the dissemination stage, it was found that the N-gain results were 0.53, and the effect size was 1.37. These results indicate that the Relation and Function worksheet based on Tri-N is effective for use in mathematics learning regarding students' critical thinking abilities.

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Analysis of Students' Mathematical Communication Ability Errors Based on the Kastolan Stages at Ban Eyoh School Thailand

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Abstract

Communication ability is one of the five basic abilities of mathematics. Understanding communication ability is one of the important things in building a learning design suitable for students' ability levels. This study analyzes the mathematical communication based on the Kastolan stages of ability of 6th-grade students at Ban Eyoh School in Thailand in answering fractional arithmetic story problems. Three students who took the sample in the study, S₁ scored 94, S₂ scored 83, and S₃ scored 72, were reviewed for high, moderate, and low communication ability. Students generally have difficulties in presenting steps in writing, especially in explaining what is known and asked about stories. Kastolan stage analysis reveals various conceptual, procedural, and technical errors, including challenges in converting mixed fractions and a lack of coherence in the solution process. Recommendations include a focus on written expression, enhanced conceptual understanding and school facilities support to improve students' mathematical communication ability. By understanding the level of students' communication ability, the results of this research can become the basis for didactical research to develop appropriate learning designs. This research can also be continued with research related to constructive feedback.

Keywords: Error Analysis; Mathematical Communication Ability; Kastolan Stages

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Abstrak

Kemampuan komunikasi merupakan salah satu dari 5 kemampuan dasar bermatematika. Memahami kemampuan komunikasi adalah salah satu hal penting untuk membangun desain pembelajarannya yang sesuai dengan level kemampuan siswa. Penelitian kualitatif deskriptif ini menganalisis kesalahan kemampuan komunikasi matematika berdasarkan tahapan kastolan pada siswa kelas 6 di Ban Eyoh School Thailand dalam menjawab soal cerita operasi hitung pecahan. Tiga siswa yang menjadi sampel dalam penelitian, S₁ dengan skor 94, S₂ dengan skor 83, dan S₃ dengan skor 72, ditinjau dari kemampuan komunikasi tinggi, sedang, dan rendah. Siswa umumnya menghadapi kesulitan dalam menyajikan langkah-langkah secara tertulis, terutama dalam menjelaskan hal yang diketahui dan ditanyakan pada soal cerita. Analisis tahapan kastolan menunjukkan berbagai kesalahan konseptual, prosedural, dan teknis, termasuk kesulitan dalam mengubah pecahan campuran dan kurangnya keteraturan dalam proses penyelesaian. Rekomendasi mencakup penekanan pada aspek tertulis, peningkatan pemahaman konsep, dan dukungan fasilitas sekolah untuk meningkatkan kemampuan komunikasi matematis siswa. Dengan memahami level kemampuan komunikasi siswa, hasil riset ini dapat menjadi dasar riset didaktis untuk mengembangkan desain pembelajaran yang sesuai. Riset ini dapat juga dilanjutkan dengan riset terkait feedback yang membangun.

INTRODUCTION

Mathematics plays an important role in education, providing a strong foundation for the development of students' logical and analytical thinking abilities (Nainggolan, 2023). In addition, mathematical communication ability is a critical aspect of learning, given the complexity of mathematical problems that are often presented in the form of stories (Afifah & Kusuma, 2021). In this context, it is important to understand the extent of students' mathematical communication ability in solving narrative problems of fraction calculation operations.

Learning mathematics is about mastering numeracy ability and students' ability to explain mathematical ideas orally and in writing. (Nasir et al., 2023). Mathematics education is directed to train students to be able to communicate clearly and precisely, use numbers, symbols, tables, or other media in explaining a problem (Sidiq et al., 2023). Therefore, mathematical communication errors, especially in narrative story problems, must be taken seriously.

Mathematics learning is interesting to look at because many students complain about how difficult it is to understand mathematics material (Lathiifah & Agustine, 2023). This happened because, in the learning process, there were still

many students who were passive and did not pay attention to the teacher's explanation (Wulandari et al., 2020). So in the learning process, a teacher must pay more attention to students who are in the classroom.

Mathematical Communication is a growing collection of resources to engage students in writing and talking about mathematics, either to learn mathematics or communicate as mathematicians. Speaking, listening, writing, and reading are examined and analyzed with a focus on verbal interactions and aspects of students' written mathematics. It also explores the nature of the mathematical writing system and how students gain access to it. (Aslan, 2021; McKenney & Reeves, 2014; Pimm, 2019)

This research makes a significant contribution to strengthening the theories of previous researchers (Aminah et al., 2018) in exploring through error analysis of students' communication ability in solving narrative problems of fraction calculation operations based on Kastolan's stages. The results of this research not only identify students' errors but also provide valuable insights into the barriers and difficulties they experience. Thus, these findings can be used as an empirical basis for developing and refining theories related to mathematical communication ability, providing a strong foundation for

the development of more effective learning strategies in the educational environment.

There are several learning methods used by mathematics teachers at Ban Eyoh School, namely lecture method learning and demonstration method learning. The first is lecture method learning where a teacher explains directly about the learning material in front of the class and the students are asked to listen and understand the things that are being explained by the teacher. After finishing the explanation, the teacher asks one of the students to re-explain what the teacher has explained. After the student finishes explaining the material, the teacher tests the student's abilities by conducting practice tasks. The second learning method, namely the demonstration method, is proven by the teacher demonstrating the exercises that have been answered by students first in front of the class then students must present back in sequence the answers to the exercises that have been given by the teacher in front of the class.

In the background of this research, previous researchers (Nugroho et al., 2023) have identified difficulties in solving narrative problems of fraction calculation operations. Relevant previous studies (Sari & Subekti, 2023) also noted that analysis of one of the students' answers revealed conceptual, procedural, and technical errors, indicating barriers to understanding fraction operations.

In this context, the formulation of the research problem is "How is students' mathematical communication ability in solving narrative problems of fraction calculation operations based on the Kastolan stage for grade VI students at Ban Eyoh School Thailand?" The purpose of this study is to describe students' mathematical communication ability in solving narra-

tive problems of fraction calculation operations based on the Kastolan stage.

According to Syukri (Syukri, 2019), contributes to the understanding of the errors commonly experienced by students in solving narrative problems of fraction calculation operations. The results of the error analysis can provide additional insights for educators and school curricula to design learning strategies that are more in line with student needs.

The importance of mathematical communication ability in solving narrative problems of fraction calculation operations is not only relevant in the scope of formal education but also has an impact on everyday life (Khofifah et al., 2022). In this era of globalization, where the need for individuals who can think critically and communicate ideas effectively is increasing, mastering mathematical communication ability becomes even more important (Amelia, 2023).

Through this research, it is hoped that it can provide concrete solutions to overcome the difficulties faced by students in understanding, solving, and communicating fraction calculation operation narrative problems. The findings are also expected to be the basis for developing more innovative and effective learning methods and can provide input for curriculum development that is more adaptive to student needs.

This research not only benefits students, teachers, and the school at Ban Eyoh School Thailand but can also serve as inspiration for similar research in other schools and educational contexts. Thus, this research not only makes a local contribution but can also play a role in improving the quality of mathematics education more broadly.

By understanding the relationship between students' mathematical communication errors in solving narrative problems of fraction calculation operations

and mathematical thinking ability (Pratiwi et al., 2020), It is hoped that this research will make a positive contribution to the development of better mathematics education at Ban Eyoh School Thailand and may also apply to other educational contexts.

METHOD

The introduction outlines how this research needs to be explained. The importance of mathematical communication has been highlighted and therefore, research into students' mathematical communication ability is necessary (Creswell, 2013).

This research adopts a descriptive qualitative approach with the research subjects of all grades VI students at Ban Eyoh School Thailand. The focus is to observe and analyze students' communication ability errors in solving fraction operation narrative problems based on the Kastolan stages. These errors are analyzed through the process of analysis as learning barriers in Brousseau's didactical theory (Brousseau, 2002; Cesaria & Herman, 2019).

Data collection techniques involved writing tests and interviews with students and mathematics teachers. Data analysis included data reduction, presentation of interview results, and conclusion to answer the research problems. Test validity and reliability were measured using the Product Moment correlation coefficient and Cronbach's Alpha. The data collection process was divided into pre-field and field stages, involving the preparation of test instruments, population characteristics, test execution, interviews, observation of students' answers, and data analysis based on the Kastolan stages. The research was conducted in Thailand as a form of collaboration between Indonesia and Thailand.

Data were obtained through a written test consisting of 5 items of fraction calculation operation narrative questions given to 18 students. Each question is given a score with a score range of $85 < n < 100$ in the high score category, $75 < n < 85$ in the moderate score category, and $n < 75$ in the low score category.

Then after obtaining written answers from students, student errors were analysed and then 3 students were selected to be interviewed. The three students were selected based on their abilities, namely: high-ability students (S_1), moderate-ability students (S_2), and low-ability students (S_3). After that, the results of the answers were assessed using indicators of understanding of mathematical concepts according to (Setiawan et al., 2023) which has been modified, namely: (1) Students' ability to connect mathematics with real objects in daily life, indicator A; (2) Students' ability to interpret events that occur in the form of fraction calculation operations, indicator B; (3) Students' communication ability in describing the things that are known in the events that occur in the form of fraction calculation operations, indicator C; (4) Students' ability to evaluate the event and solve the problems in the event, indicator D; and (5) Students' ability to draw conclusions and communicate back the results that have been resolved in the event, indicator E

After analyzing students' communication ability based on indicators of understanding of mathematical concepts, then the students' answers were analyzed again based on their Kastolan errors. Errors in working on maths problems based on Kastolan stages namely: (1) **Conceptual Error (KK)**: student errors in choosing formulas, students do not answer the questions correctly, and students do not do the problems that have been given; (2) **Procedural Error (KP)**: student

errors in solving the problem with the correct steps, students do not simplify the answer to the problem, students do not write the known and questionable information, and students do not answer sequentially solving the problem, and (3) **Technical Error (KT)**: students are wrong in calculating numbers, writing mathematical signs of punctuation, and writing coefficient constants and variables.

After producing data that has been analyzed based on indicators of concept understanding and analyzed for errors based on Kastolan stages, then the results of the data are presented by defining the errors made by S1. S2 and S3 are based on communication ability and Kastolan stages.

The research stages are as follows:

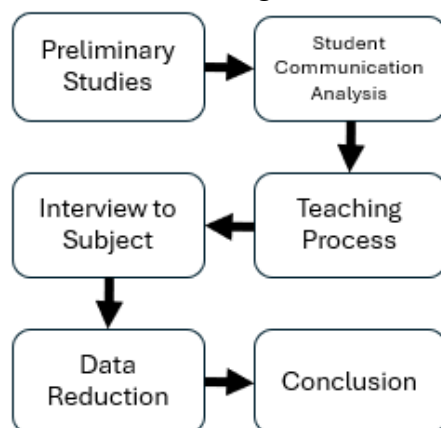


Figure 1. Research step

RESULT AND DISCUSSION

This study was conducted at Ban Kadeng Primary School in southern Thailand. Most of the students in the school are Muslim because Ban Kadeng is in the southern area of Thailand which is adjacent to Malaysia. There are many people of Malay race in the area. Here is the learning situation in the school:



Figure 2. learning situation at the research subject

After learning, students' concept understanding was measured. The following table presents data from the results of research on students with exposure to data analysis as shown in Tabel 1.

Table 1. Results of students' understanding of mathematical concepts.

| Subject | Indicators of Concept Understanding | | | | |
|----------------|-------------------------------------|-----------------|-----------------|-----------------|-----------------|
| | Questi- on 1 | Questi- on 2 | Questi- on 3 | Questi- on 4 | Questi- on 5 |
| S ₁ | BDE | BCDE | BCDE | BCDE | BCDE |
| S ₂ | CE | BCDE | - | - | BCD |
| S ₃ | - | B | - | B | BDE |

Based on Table 1 above, S₁ still does not fulfill indicator A. From question 1 to question 5, no indicator A is fulfilled. It can be defined that S₁ has not been able to connect mathematics with real objects in everyday life (Fitriani et al., 2021). Then in question number 1, indicator C is also not fulfilled, which means that S₁ has not been able to explain what things are known and asked in the problem. Indicators B, D, and E can be fulfilled by S₁ as evidenced by the ability to write and mention the answer to the problem correctly and structured using the fraction operation method, being able to write and re-examine the answers obtained by answering the questions obtained by recalculating, as well as carrying out proof in solving the problem and having written and mentioned the conclusion correctly. Indicators B, D, and E can be fulfilled by S₁ as evidenced by the ability to write and mention the answer to the problem correctly and structure using the fraction operation method, being able to write and recheck the answers obtained by answering the questions obtained by recalculating, as well as carrying out proof in solving the problem and having written and mentioned the conclusion correctly.

S₂ was unable to fulfill all indicators of concept understanding in questions number 3 and 4. But in question number 1, S₂ can understand 2 indicators, namely using the fraction operation method by the concept and mentioning and writing conclusions correctly. In question number 2, S₂ is only unable to fulfill indicator A,

namely not being able to connect mathematics with real objects in everyday life. And for question number 5, S₂ is unable to fulfill indicators A and E, namely not being able to connect mathematics with real objects in everyday life, and not being able to mention and write conclusions appropriately.

The results of student work at the school are as Figure 3.

Handwritten mathematical work showing four fraction calculations:

- $2\frac{1}{2} + 1\frac{1}{6} = 2\frac{1}{2} + 1\frac{1}{6} = 3\frac{5}{6}$
- $\frac{5}{2} - \frac{3}{4} = \frac{10}{4} - \frac{3}{4} = \frac{7}{4}$
- $\frac{8}{3} - 1\frac{1}{2} = \frac{8}{3} - \frac{3}{2} = \frac{16}{6} - \frac{9}{6} = \frac{7}{6}$
- $5 - 2\frac{1}{3} = \frac{15}{3} - 2\frac{1}{3} = \frac{6}{3}$

Figure 3. results of student work at school

Then for S₃, it seems that he is still unable to fulfill all indicators in questions number 1 and 4, and is only able to fulfill aspect B in questions number 2 and 4. In question number 5, S₃ has not been able to fulfill indicators A and C, namely not being able to connect mathematics with real objects in everyday life and explain things that are known in the events that occur in the form of fraction calculation operations.

Furthermore, Ulfa and Kartini (Ulfa & Kartini, 2021) stated a significant contribution to the theoretical understanding of mathematical communication ability, especially in the context of solving story

problems of fraction calculation operations based on the Kastolan stage. Student error analysis provides an in-depth look at the aspects that need more attention in the learning process (Dawa et al., 2020). This research investigates the errors in the mathematics communication ability of grade 6 students at Ban Eyoh School Thailand based on the Kastolan stages. The following is a discussion of research on mathematics communication ability errors of grade 6 students at Ban Eyoh School Thailand based on the Kastolan stages as follows.

Table 2. Student-generated question scores based on the accuracy of answering questions

| Subject | Score | | | | | Total Score |
|---------|-------|----|----|----|----|-------------|
| | 1 | 2 | 3 | 4 | 5 | |
| S1 | 19 | 18 | 18 | 18 | 17 | 90 |
| S2 | 17 | 16 | 14 | 14 | 15 | 76 |
| S3 | 12 | 13 | 12 | 13 | 15 | 65 |

Table 3. Kastolan errors made by students

| Subject | Kastolan Error | | | | |
|---------|----------------|------------|------------|------------|-------|
| | 1 | 2 | 3 | 4 | 5 |
| S1 | KP | KP | KP | KP | KP,KT |
| S2 | KK, KP, KT | KP | KK, KP | KP, KT | KP |
| S3 | KK, KP, KT | KK, KP, KT | KK, KP, KT | KK, KP, KT | KP |

Based on Table 2 and Table 3 above, S1 shows good ability in understanding and solving fraction narrative problems. (Pangaribuan et al, 2021). S1 showed high mathematical communication ability with a total score of 94. However, there were errors in the procedural aspect, where S1 failed to present in writing what was known and asked in the narrative problem. Technical errors only occurred in problem number 5, where S1 made errors in multiplying fractions, probably due to lack of focus and rushing. Although there were procedural errors due to not putting the steps in writing, students were still able to explain the steps well orally. Although there are some technical errors in

the calculation of multiplication in some problems, in general, students understand the concept of fractions well.

S2 showed moderate mathematical communication ability with a total score of 83. S2's main error lies in the conceptual aspect of problem number 1, where S2 is erroneous in converting mixed fractions into ordinary fractions. In addition, S2 tended not to write the things known and asked in the narrative problem. S2 had errors at the conceptual stage in problem number 1, where they made errors in converting mixed fractions. At the procedural stage, S2 often did not write the things known and asked in the narrative problem. Technical errors occurred because they were too hasty in calculating. S2 also showed the ability to convert mathematical statements, although there were technical errors in some problems. (Hasibuan et al., 2022). In general, there are conceptual and procedural errors in understanding the concept of fraction calculation operations. Recommendations for improvement involve further practice in interpreting events, strengthening the understanding of the concept of fraction operations, and practicing speed in calculating thoroughly. With the implementation of these recommendations, S2 is expected to improve his mathematical communication ability and understand the concept of fraction operations better.

Some of the student's work can be seen in the Figure 4 below.

Handwritten mathematical work showing five fraction calculations with steps and errors:

- $2\frac{1}{2} + 2\frac{1}{6} = \frac{5}{2} + \frac{2}{3} = \frac{5 \times 3}{2 \times 3} + \frac{2 \times 2}{3 \times 2} = \frac{15}{6} + \frac{4}{6} = \frac{19}{6}$
- $\frac{5}{7} - \frac{3}{4} = \frac{5 \times 4}{7 \times 4} - \frac{3 \times 7}{4 \times 7} = \frac{20}{28} - \frac{21}{28} = \frac{-1}{28}$
- $\frac{15}{2} - \frac{8}{3} = \frac{15 \times 3}{2 \times 3} - \frac{8 \times 2}{3 \times 2} = \frac{45}{6} - \frac{16}{6} = \frac{29}{6}$
- $\frac{5}{7} - 2\frac{1}{3} = \frac{5}{7} - \frac{7}{3} = \frac{5 \times 3}{7 \times 3} - \frac{7 \times 7}{3 \times 7} = \frac{15}{21} - \frac{49}{21} = \frac{-34}{21}$
- $\frac{3}{5} \times 21 = \frac{3 \times 21}{5} = \frac{63}{5}$

Figure 4. S2 and S3 work

S₃ showed low mathematical communication ability with a total score of 72. There were several errors in each aspect of the assessment. In problem number 1, S₃ was wrong in choosing the calculation operation and did not simplify the results of the fraction operation. In addition, S₃ often failed to write down the things known and asked in the story problem. S₃ has errors at each stage of Kastolan. At the conceptual stage, S₃ was wrong in choosing the calculation operation. At the procedural stage, S₃ failed to present in writing the things known and asked in the narrative problem and did not simplify the answer. Technical errors occur when calculating sums. There are several S₃ Kastolan errors, especially in the aspects of conceptual, procedural, and technical errors (Ayu *et al.*, 2023). In overcoming this, more practice and understanding of mathematical concepts, especially in fraction calculation operations, is needed.

This study provides a good insight into students' mathematical communication ability errors at Ban Eyoh School Thailand, focusing on conceptual, procedural, and technical aspects. Recommendations for improvement can focus on strengthening the understanding of basic mathematical concepts and improving students' ability to present answers in writing and simplify the results of fraction operations.

Discussion

There are 4 things found in this study that

need to be improved by teachers. The improvement of the teacher's actions can encourage students' mathematical communication ability.

(1) Listening for comprehension, reading comprehension, and recording necessary mathematical information presented in mathematical texts or the speech or writing of others. In the practice found, the teacher still acts formally. Students obtain information from the teacher without acting independently. Finding information independently is important for building communication ability and is in line with some previous research (Aslan, 2021; Clements & Sarama, 2004; Hockings *et al.*, 2018; Livingston, 2012; Polya, 1962; Skemp, 1987).

(2) Presenting, expressing (speaking or writing) mathematical content, ideas, and solutions in interaction with others (with appropriate completeness and rigor). In the learning practice carried out, the teacher still explains too much material. Students are rarely allowed to discuss with friends. However, this cannot be explained further whether the absence of opportunities is because the teacher does not provide opportunities or students are unable to discuss independently. However, this obstacle indicates a problem that needs to be solved further. Providing opportunities for discussion in knowledge formation is important and needs to be done by students to build more permanent schemes (Brousseau, 2002; Chevallard & Bosch, 2020; Dubinsky, 2000; Uyen *et al.*, 2021)

(3) Effectively use mathematical language (numbers, letters, symbols, charts, graphs, logical connections) combined with common language or physical gestures when presenting, solving problems, and evaluating mathematical ideas in interaction (discussing, arguing) with others. In modern development, communication is done verbally. Students can do

this through apps, watching videos, and various other means of communication. Teachers need to improve their ability to operate various modes of teaching so that students can communicate more easily. The process of using these modes by both teachers and prospective teachers is important because it will be able to build communication in students (Assis et al., 2018; Gonzales et al., 2020; Graham et al., 2020; Önal, 2019; Uyen et al., 2021; Vogt & Rogalla, 2009).

(4) Showing confidence when presenting, expressing, asking questions, discussing, and debating ideas related to mathematics. In the practice that has been done, teachers still need to build students' confidence. Teachers need to provide sufficient motivation to students. One way is to provide opportunities for students to conduct inquiry and student-centered learning. This is certainly in line with some research on students' self-efficacy and confidence in mathematics (Ferreira-Neto et al., 2023; Gonzales et al., 2020; Nzomo et al., 2023; Orakçı et al., 2023; Septiyana et al., 2019; Shah & Bhat-tarai, 2023).

Implication on research

This study was conducted as collaborative research between Indonesia and Thailand. However, it does not rule out the possibility that the results of this study become the basis for didactic design research to develop learning designs that mainstream students' mathematical communication. In addition, research on providing feedback to students that can build students' mathematical communication can also be carried out. However, it does not rule out the possibility that the results of this study become the basis for didactic design research to develop learning designs that mainstream students' mathematical communication.

Limitation

This research was conducted in Thailand as part of a collaborative research program. However, the characteristics of the predominantly Malay students (conducted in southern Thailand) are comparable to schools in Malaysia, Indonesia, and Brunei Darussalam. However, the limitations of the collaborative partners meant that the research subject could not be pluralized across all ethnicities of students.

The limitations of the study include the different languages used, different scripts, and students' lack of ability to use English as a universal language. This affected the data collection process, especially in terms of tests and interviews. Nonetheless, these limitations were overcome by adapting the tests to the Thai script and communicating with the students in a language they understood.

CONCLUSION

Based on the analysis, students with high communication ability (S1) scored 94 and tended to focus less on the written aspect, especially in presenting what is known and asked in the narrative problem. Low-ability students (S3) with a score of 72 showed similar errors to S1 and S2 and appeared to have difficulty understanding the concept of fraction calculation operations. Recommendations include an emphasis on the written aspect, improving concept understanding, and providing school facilities to support mathematics learning.

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Effectiveness of TikTok-assisted Learning Supplement to Improve Students' Concept Understanding Ability and Learning Interest

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Abstract

The use of social media such as TikTok in mathematics education and row and sequence materials is still rarely explored, although it has the potential to change the paradigm of presenting supplementary materials. This is because generally additional material is presented through platforms that are specifically for learning such as Geogebra, learning modules, or Kahoot. This study aims to determine the effectiveness of TikTok-assisted learning supplements on the ability to understand concepts and students' interest in learning the material of arithmetic rows and series from the results of test work and questionnaires through pre-test and post-test that have been carried out. This study involved students of class XI IPA 5 SMA Negeri 1 Manonjaya as the sample, with the population of all class XI students in the school. This research combines quasi-experimental method and quantitative approach. This study found two important things: First, the use of TikTok-assisted learning supplements proved to be effective in improving students' conceptual understanding of arithmetic rows and sequences. Second, the use of TikTok-assisted learning supplements did not show effectiveness in increasing students' learning motivation. This is evidenced by the higher interest in learning in the experimental class compared to the control class, as well as a significant increase in the average value of N-Gain (normalized gain) in concept understanding ability. For this reason, other research is needed regarding the effectiveness of a social media in the context of learning on the ability to understand concepts and students' interest in learning by using other social media and/or other cognitive aspects or affective aspects.

Keywords: Effectiveness; Learning Supplement; TikTok; Concept Understanding Ability; Learning Interest.

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Abstrak

Penggunaan media sosial seperti TikTok dalam pendidikan matematika dan materi barisan dan deret masih jarang dieksplorasi, meskipun memiliki potensi untuk mengubah paradigma penyajian materi tambahan. Hal ini karena umumnya materi tambahan disajikan melalui platform yang khusus untuk pembelajaran seperti Geogebra, modul pembelajaran, atau Kahoot. Penelitian ini bertujuan untuk mengetahui efektivitas suplemen pembelajaran berbantuan TikTok terhadap kemampuan pemahaman konsep dan minat belajar peserta didik pada materi barisan dan deret aritmetika dari hasil pengerjaan tes dan kuesioner melalui pre-test dan post-test yang telah dilaksanakan. Penelitian ini melibatkan siswa kelas XI IPA 5 SMA Negeri 1 Manonjaya sebagai sampel, dengan populasi seluruh siswa kelas XI di sekolah tersebut. Penelitian ini menggabungkan metode kuasi-eksperimen dan pendekatan kuantitatif. Penelitian ini menemukan dua hal penting: Pertama, penggunaan suplemen pembelajaran berbantuan TikTok terbukti efektif dalam meningkatkan pemahaman konseptual siswa terhadap materi barisan dan deret aritmatika. Kedua, penggunaan suplemen pembelajaran berbantuan TikTok tidak menunjukkan efektivitas dalam meningkatkan motivasi belajar siswa. Hal ini dibuktikan dengan minat belajar yang lebih tinggi pada kelas eksperimen dibandingkan kelas kontrol, serta peningkatan nilai rata-rata N-Gain (gain ternormalisasi) yang signifikan dalam kemampuan pemahaman konsep. Untuk itu, diperlukan penelitian lain mengenai efektivitas suatu media sosial dalam konteks pembelajaran terhadap kemampuan pemahaman konsep dan minat belajar peserta didik dengan menggunakan media sosial lain dan/atau aspek kognitif atau aspek afektif lain.

INTRODUCTION

Mastering mathematical concepts, especially the material of rows and series, is the key for students to solve problems well. However, in fact, many students have difficulty understanding the concepts and procedures that should be used (Annisa & Kartini, 2021). This encourages the need for pupils' comprehension of mathematical ideas to be improved (Maarif et al., 2022).

One of the efforts to improve students' concept understanding and interest in learning is by using various learning media. Studies have often shown how beneficial it is to use media in math training. Examples of this include instructional videos (Aldi et al., 2022), VCDs (Farida, 2015), ICT tools (Rusmana, 2012), animated films (Safitri et al., 2020), Ispring Presenter software (Anwar et al., 2019), and even entertaining games like Kahoot! (Wigati, 2019). By judiciously selecting appropriate learning media, teachers can significantly elevate students' grasp of mathematical concepts and cultivate a more stimulating learning environment. This is in line with the goal of education, aiming to nurture a competent and mathematically astute younger generation.

Concept understanding ability is an individual's ability to master the mathematical ideas taught. This is indicated by the ability to complete related tasks quickly, precisely, efficiently, and smoothly (Sari, 2017). Duffin & Simpson (2000) explained that the ability to understand concepts is manifested in three aspects, namely the ability to reformulate concepts that have been taught, the ability to apply concepts in various situations and contexts, and the ability to understand the implications of the concepts learned. In addition, Kilpatrick (2001) states that concept understanding refers to the ability to understand ideas thoroughly and functionally, which also supports the ability to remember them well. In other words, the ability to understand mathematical concepts refers to an individual's ability to master mathematical ideas, apply them appropriately and flexibly, and connect their application to a broader context.

Conceptual understanding plays an important role in helping learners to avoid critical errors when solving problems, as well as enabling them to accelerate learning by finding deeper correlations between seemingly unrelated situations. With a strong conceptual understanding

of mathematics, students can connect ideas and methods and explain the reasoning behind facts. This ability fosters self-confidence, which is the foundation for achieving higher levels of understanding (Kilpatrick, 2001).

However, based on data from the 2022 PISA study, Indonesia obtained an average score of 366 in mathematics, which decreased from the 2018 PISA study with a score of 379 (OECD, 2023). This shows that students' understanding of mathematical concepts is low. Students' low understanding of mathematical concepts is a major obstacle in achieving learning objectives.

Understanding a concept can be done through an interesting learning activity design, such as exploring deeper knowledge and providing appropriate and fun concepts (Santrock, 2011). This explorative activity is done so that students no longer memorize a concept but already understand the concept.

Factors that influence the success of students in learning according to Ngalim (2007) are divided into two types, namely: 1) Individual factors, which include individual maturity or understanding, level of training intelligence, personal motivation, and personal factors that affect learning; 2) Social factors, which include the role of family and household circumstances, the influence of teachers and teaching methods, the availability of tools, the learning environment and available opportunities, and social motivation from the surrounding environment; and 3) Psychological factors of learners.

The purpose of learning mathematics at school has a focus on the ability to understand concepts (Depdiknas, 2006). The use of social media, especially TikTok, as a learning support video has been proven effective in improving understanding of subject matter. The use of social media, particularly TikTok, as a learning

tool has been shown to be effective in aiding understanding of subject matter (Amelia et al., 2022). Social media such as TikTok, Twitter, and Facebook not only act as information dissemination platforms, but also become powerful learning tools (Basch et al., 2022). This is reinforced by Pujiono's research (2021) which found that the use of TikTok in learning has a positive effect, increases learning interest, and supports the achievement of math learning goals at school.

High learning interest usually has an impact on high learning achievement, on the other hand, a lack of low learning interest results in low learning achievement (Djamarah, 2002). This is in line with research conducted by Purnama (2016) which states that increasing students' interest in learning mathematics first is believed to be a more effective approach in improving their mathematics learning achievement. This will cause learners to feel more interested and like math subjects without any pressure. With a strong interest, learners will give their full attention and face difficulties as challenges that can be overcome. They will also be more eager in solving various math problems and will eventually produce a positive impact on overall math learning achievement.

Interest in learning is an innate trait or character that inspires and motivates a person to have a sustained preference for a particular area of learning or topic of study (Krapp, 1999). According to Lai (2010), interest in learning is a personal choice related to the learning process, which sometimes includes an individual's prioritization of certain activities over others and involves positive psychological experiences when interacting with situations that encourage the desire to learn more. In addition, Kpolovie et al. (2014) state that interest in learning is an individual's natural drive to explore knowledge

triggered by interest in the subject matter, reflected through feelings of pleasure. Thus, interest in learning can be interpreted as an innate characteristic that encourages individuals to choose and engage in learning on an ongoing basis, triggered by a sense of pleasure and interest in a particular topic.

The traditional approach to learning, refers to a method where the educator gives a lecture with the help of Power-Point slides delivered through a projector onto a large screen or whiteboard, with learners following the educator and giving responses by raising their hands. According to Yu (2023), although this method is no longer considered sufficient to meet students' learning needs, combining important information with mobile apps can spark students' curiosity and passion for learning.

Social media platforms like TikTok not only provide entertainment, but also have tremendous potential as a useful learning tool. Septiani & Abadi (2022) research proves that the use of TikTok can increase students' motivation in learning mathematics. This is in line with other findings, such as Pechenkina *et al.* (2017) who showed that mobile apps can improve memory retention, Yu (2020) who found that TikTok can stimulate curiosity in learning, and Ladeji-Osias *et al.* (2018) who proved that TikTok can improve student achievement.

Efforts to increase low student interest in learning, as asserted by Putri *et al.* (2019), are in line with the strategy of using media and variations in teaching techniques. This is supported by Fuad & Zuraini (2016) who mention several elements that influence learning enthusiasm, namely internal student factors which include: a) Physical aspects, and b) Psychological aspects (kejiwaan). 2) Factors outside the learner's self (external), consisting of: a) Family, b) School; and 3)

Community environment. The utilization of social media such as YouTube, Instagram, TikTok, and similar applications as learning tools or media, for example by making learning videos of mathematics and other teaching materials, can have a positive impact on students' interest in learning mathematics (Septiani & Abadi, 2022).

The use of the TikTok application as a learning media has several advantages and positive impacts (Fauziyah *et al.*, 2022), including: 1) Influence on skill abilities, such as increasing reading skills, speaking skills, and listening skills; and 2) Influence on students' interest in learning. This is due to the popularity of the TikTok application today which affects its image as a product that is favored by all groups so that when its use is involved in the current generation it will increase their interest in learning. In addition, in the context of mathematics learning, according to Amelia *et al.* (2022) the use of TikTok as a learning supplement can make it easier for students to understand learning materials and help change learning from abstract to more real.

Awareness of mathematical concepts is fundamental for students before solving problems. However, there are still difficulties in the classroom because some learners are more likely to memorize concepts without deep understanding. Therefore, understanding mathematical concepts is not only an important foundation, but also requires an approach that considers internal and external factors to ensure optimal learning progress. Utilizing social media platforms such as YouTube, Instagram, and TikTok as a means of distributing learning supplements is an innovative strategy to improve the quality of existing learning resources Amelia *et al.* (2022).

Students' level of learning success is closely related to their learning interest,

which reflects the tendency and excitement towards a subject. Iskandarwassid & Sunendar (2008) emphasize that learning interest indicators such as enjoyment, participation, attention and interest are very important in assessing the level of learning interest. Increasing students' enthusiasm in learning, especially in mathematics, has been proven to improve their academic performance. Diverse learning resources, including cutting-edge strategies such as the use of TikTok, can be an effective tool to overcome low interest in learning (Putri et al., 2019). Therefore, to improve overall learning achievement, educators need to have a thorough understanding of the elements that drive interest in learning and implement appropriate learning practices.

At SMA Negeri 1 Manonjaya, there are problems in concept understanding and students' interest in learning mathematics. The results of interviews with mathematics teachers show that students' weak basic math skills are the main factor in their lack of enthusiasm in learning. One way to overcome difficulties and low interest in learning is to use technology facilities provided at school in learning. The availability of technological facilities at SMA Negeri 1 Manonjaya such as computer laboratories, laptops, and infocus is good enough, but other media are needed to improve students' concept understanding ability and interest in learning.

Based on the description of the above problems regarding the ability to understand concepts and students' interest in learning, this study aims to determine the effectiveness of TikTok-assisted learning supplements to improve students' concept understanding ability and interest in learning.

METHOD

This research was conducted at SMA Negeri 1 Manonjaya which is located at Jalan Patrol Kulon RT/RW 03/01, Margaluyu Village, Manonjaya Subdistrict, Tasikmalaya Regency, West Java Province. The quantitative approach was used in this study because it aims to evaluate the effectiveness of learning supplements on students' concept understanding ability and learning interest. The data used were the pre-test and post-test results of the concept understanding ability test, as well as a questionnaire of students' interest in learning. Therefore, the research method used was quasi-experiment.

Furthermore, the population in this study were all students of grade XI SMA Negeri 1 Manonjaya, consisting of 7 science classes and 5 social studies classes. Through the application of simple random sampling technique with the help of "RANDBETWEEN" formula in Excel, XI IPA 5 class was selected as the research sample that used TikTok-assisted learning supplement, while XI IPA 6 class was selected as the research sample that did not use TikTok-assisted learning supplement. This study used the "Randomized Pretest-Posttest Control Group Design" by Bulus (2021) to compare the pre-test and post-test results of two groups given different treatments. This research design is presented in Figure 1.

| | | | |
|---|---|---|---|
| R | O | X | O |
| R | O | | O |

Figure 1. Research Design

Description:

R = random sampling

O = pre-test observation before treatment or post-test after treatment in the form of a learning interest questionnaire

X = treatment in the form of learning supplements assisted by TikTok

In this study, the quality of research data is influenced by two main factors according to Sugiyono (2017), namely the quality of research instruments and the quality of the data collection process. The quality of research instruments includes the validity and reliability of the tools used, while the quality of the data collection process is related to the methods used to collect data.

The results of the test instrument of the students' concept understanding ability test questions with indicators of concept understanding ability according to Hendriana et al. (2017), namely: First, restate a concept (PT1); Second, classify objects according to certain properties (in accordance with the concept) (PT2); Third, provide examples and non-examples of a concept (PT3); Fourth, present concepts in various forms of mathematical representation (PT4); fifth, developing necessary or sufficient conditions of a concept (PT5); sixth, using, utilizing, and selecting certain procedures or operations (PT6); and seventh, applying concepts or problem-solving algorithms (PT7), the correlation coefficient value regarding the validity of each item is presented in Table 1.

Table 1. Calculation Results of Validity Test of Test Questions for Students' Concept Understanding Ability

| Item No. | Indicator | r_{xy} (r count) | r table (N = 30) |
|----------|-----------|-----------------------|---------------------|
| 1. | PT1 | 0,504 | 0,374 |
| 2. | PT2 | 0,516 | 0,374 |
| 3. | PT3 | 0,562 | 0,374 |
| 4. | PT4 | 0,449 | 0,374 |
| 5. | PT5 | 0,793 | 0,374 |
| 6. | PT6 | 0,486 | 0,374 |
| 7. | PT7 | 0,521 | 0,374 |

The results of the reliability test of students' concept understanding ability test questions are presented in Table 2.

Table 2. Calculation Results of Reliability Test of Test Questions for Students' Concept Understanding Ability

| Cronbach's Alpha | r table (N = 30) | Decision | Category |
|------------------|---------------------|----------|----------|
| 0,604 | 0,374 | Reliable | High |

The results of Table 1 show that the results of the validity test of each item of the learner's concept understanding ability test instrument meet the valid criteria. This indicates that all items in the test can be used as a tool to measure students' concept understanding ability. Furthermore, from Table 2, the reliability coefficient value for the test questions of students' concept understanding ability (r_{11} or r count) shows a Cronbach's Alpha value of 0.604, which is in the high category according to the predetermined criteria, namely the interval $0,60 < r_{11} \leq 0,80$. Thus, the instrument can be trusted to be used in research.

The results of the trial of the instrument of the questionnaire statement of students' learning interest with indicators of learning interest according to Iskandarwassid & Sunendar (2008), namely: first, feelings of pleasure (PS1-PS6); second, learners' interest (KTPD1-KTPD4); third, learners' attention (PPD1-PPD7); and fourth, learners' involvement (KLDP1-KLPDg), obtained the correlation coefficient value regarding the validity of each statement item presented in Table 3.

Table 3. Calculation Results of Validity Test of Student Learning Interest Questionnaire Statement

| Item No. | Indicator | r_{xy} (r count) | r table (N = 30) |
|----------|-----------|-----------------------|---------------------|
| 1. | PS1 | 0,460 | 0,374 |
| 2. | PS2 | 0,639 | 0,374 |
| 3. | PS3 | 0,623 | 0,374 |
| 4. | PS4 | 0,704 | 0,374 |
| 5. | PS5 | 0,823 | 0,374 |
| 6. | PS6 | 0,407 | 0,374 |
| 7. | KTPD1 | 0,794 | 0,374 |
| 8. | KTPD2 | 0,794 | 0,374 |
| 9. | KTPD3 | 0,909 | 0,374 |

| Item No. | Indicator | r_{xy} (r count) | r table (N = 30) |
|----------|-------------------|-----------------------|---------------------|
| 10. | KTPD ₄ | 0,749 | 0,374 |
| 11. | PPD ₁ | 0,689 | 0,374 |
| 12. | PPD ₂ | 0,599 | 0,374 |
| 13. | PPD ₃ | 0,608 | 0,374 |
| 14. | PPD ₄ | 0,591 | 0,374 |
| 15. | PPD ₅ | 0,780 | 0,374 |
| 16. | PPD ₆ | 0,721 | 0,374 |
| 17. | PPD ₇ | 0,733 | 0,374 |
| 18. | KLPD ₁ | 0,678 | 0,374 |
| 19. | KLPD ₂ | 0,658 | 0,374 |
| 20. | KLPD ₃ | 0,485 | 0,374 |
| 21. | KLPD ₄ | 0,551 | 0,374 |
| 22. | KLPD ₅ | 0,503 | 0,374 |
| 23. | KLPD ₆ | 0,600 | 0,374 |
| 24. | KLPD ₇ | 0,535 | 0,374 |
| 25. | KLPD ₈ | 0,532 | 0,374 |
| 26. | KLPD ₉ | 0,509 | 0,374 |

The results of the reliability test of the student interest questionnaire statement are presented in Table 4.

Table 4. Calculation Results of Reliability Test of Student Learning Interest Questionnaire Statements

| Cronbach's Alpha | r table (N = 30) | Decision | Category |
|------------------|---------------------|----------|-----------|
| 0,910 | 0,374 | Reliable | Very High |

The results of Table 3 show that the results of the validity test of each item of the student interest questionnaire statement instrument meet the valid criteria. This shows that all statement items can be used as a tool to measure students' interest in learning. Furthermore, from Table 4, the reliability coefficient value for the learner interest questionnaire statement (r_{11} or r count) shows a Cronbach's Alpha value of 0.910, which is in the very high category according to the predetermined criteria, namely the interval $0,80 < r_{11} \leq 1,00$. Thus, the instrument can be trusted to be used in research.

The data collection techniques used in this study were concept understanding ability tests and student interest questionnaires. The test used in this study is a

concept understanding ability test that refers to (Hendriana et al., 2017), namely restating a concept, classifying objects according to certain properties (in accordance with the concept), providing examples and non-examples of a concept, presenting concepts in various forms of mathematical representation, developing necessary or sufficient conditions for a concept, using, utilizing, and selecting certain procedures or operations, and applying concepts or problem solving algorithms. In this study, the concept understanding ability test consists of 7 questions with a minimum score of 0 and a maximum score of 21. The concept understanding ability test grid is presented in Table 5.

Table 5. Scoring Guidelines for Concept Understanding Ability Test

| No | Indicator | Description | Score |
|----|---|---|-------|
| 1. | Restate a concept | No answer | 0 |
| | | Although there are still many mistakes | 1 |
| | | Although not yet precise | 2 |
| | | Can restate a concept correctly | 3 |
| 2. | Classify objects according to certain properties (in accordance with the concept) | No answer | 0 |
| | | Although there are still many mistakes | 1 |
| | | Although not yet precise | 2 |
| | | Can classify objects according to certain properties in accordance with the concept appropriately | 3 |
| 3. | Provide examples and non-examples of a concept | No answer | 0 |
| | | Although there are still many mistakes | 1 |
| | | Although not yet precise | 2 |
| | | Can give examples and non-examples of a concept correctly | 3 |
| 4. | Present concepts in various forms of mathematical | No answer | 0 |
| | | Although there are still many mistakes | 1 |
| | | Although not yet precise | 2 |
| | | Can present concepts | 3 |

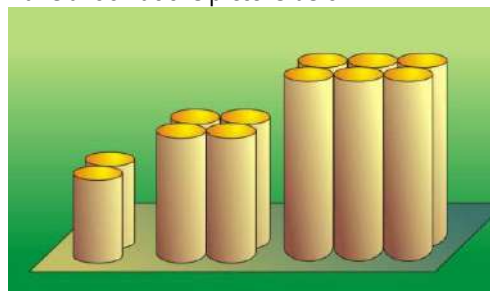
| No | Indicator | Description | Score |
|----|--|--|------------------|
| | representations | in various forms of mathematical representations appropriately | |
| 5. | Develop necessary or sufficient condition of a concept | No answer Although there are still many mistakes Although not yet precise Can develop necessary or sufficient conditions of a concept appropriately | 0 1 2 3 |
| 6. | Use, utilize, and select specific procedures or operations | No answer Although there are still many mistakes Although not yet precise Can use and utilize and select certain procedures or operations appropriately | 0 1 2 3 |
| 7. | Apply problem-solving concepts or algorithms | No answer Although there are still many mistakes Although not yet precise Can apply problem-solving concepts or algorithms appropriately | 0 1 2 3 |

The concept understanding ability test questions in this study are presented in Table 6.

Table 6. Test Questions for Concept Understanding Ability

| | |
|----|--|
| 1. | Which is an arithmetic sequence and which is an arithmetic series? Explain! |
| a. | 1, 4, 7, 10, ..., 91, 94, 97, 100 |
| b. | 1 + 4 + 7 + 10 + ... + 91 + 94 + 97 + 100 |
| c. | 36 + 32 + 28 + 24 + ... + (-24) + (-28) + (-32) + (-36) |
| d. | ..., (-36), (-32), (-28), (-24), ..., 24, 28, 32, 36, ... |
| 2. | A number as 12, 16, 20, 24, ..., U_n . Determine: |
| a. | The formula of the n th term and the formula of the sum of the n th term |
| b. | The value of the 10th term plus the sum of the 8th term |
| 3. | Which of the following is an arithmetic sequence? |

- | | |
|----|--|
| a. | 0, 5; 0, 75; 1; 1, 25; 1, 5; 1, 75; 2; ... |
| b. | 4, 1, -2, -5, -8, -11, -14, ... |
| c. | 5, 8, 11, 14, 18, 21, 24, ... |
| d. | $\frac{4}{5}, 2, 3\frac{1}{5}, \frac{22}{5}, 5\frac{3}{5}, \frac{34}{5}, \dots$ |
| 4. | An arithmetic sequence is expressed by $1 + 4 + 7 + \dots + 91 + 94 + 97$. Find another formula that can calculate the entire arithmetic sequence! (other than $S_n = \frac{n}{2}(2a + (n - 1)b)$ dan $S_n = \frac{n}{2}(U_1 + U_n)$) |
| 5. | The 4th term and the 12th term are 13 and 29 respectively and the difference between each term is 2. Find the 100th term! |
| 6. | Take a look at the picture below! |



Based on the figure, find the value of the first term and the number of terms if the sum of all the terms is 18,360!

- | | |
|----|---|
| 7. | A high school student is conducting an experiment on gravitational force. The experiment was conducted by dropping a marble from the top of a 327 meter high building and the bounce decreased by 3 meters each bounce. |
| a. | What is the amount of height the marble traveled until it stopped? |
| b. | After what number of bounces does the marble have a total height of 6,501 meters? |

The questionnaire used in this study is a learning interest questionnaire that refers to Iskandarwassid & Sunendar (2008), namely feelings of pleasure, learner interest, learner attention, and learner involvement with the Likert scale form. The Likert scale questionnaire was chosen because it requires students to express their perceptions and opinions in the form of a scale that has gradations from very positive to very negative. In addition, this method can provide an overview of individual or group attitudes towards the potential and challenges of a subject

(Sugiyono, 2017). In this study, the learner interest questionnaire consisted of 26 statement items with a minimum score of 0 and a maximum score of 130. The lattice of the learner interest questionnaire is presented in Table 7.

Table 7. Scoring Guidelines for the Student Learning Interest Questionnaire

| Statement | Alternative Answer | | | | |
|-----------|--------------------|---|---|----|-----|
| | SS | S | N | TS | STS |
| Positive | 5 | 4 | 3 | 2 | 1 |
| Negative | 1 | 2 | 3 | 4 | 5 |

Scoring was carried out after the learning process ended by conducting two tests of concept understanding ability and filling out a learning interest questionnaire by students, both those who used TikTok as a media supplement to be teaching materials and those who did not. Thus, researchers will compare the level of students' interest in learning and data on the results of students' concept understanding ability between the two groups to assess the impact of using TikTok-assisted learning supplements.

The analysis technique used in this research is quantitative method. In quantitative data analysis, information is taken using numbers and calculations using statistical methods. The data is then grouped into certain categories using special tables, thus facilitating analysis using the IBM SPSS Statistics 25 for Windows program. The analytical tool used to test effectiveness is N-Gain Score analysis by conducting Normality test, Homogeneity test, and Independent Sample T-Test test. The N-Gain Score (normalized gain) formula according to Hake (1999, p. 2) is as follows.

$$\langle g \rangle = \frac{\% \langle G \rangle}{\% \langle G \rangle_{\max}} = \frac{(\% \langle S_f \rangle - \% \langle S_i \rangle)}{(100 - \% \langle S_i \rangle)}$$

Description:

- $\langle g \rangle$ = average value of normalized gain
- $\langle G \rangle$ = average value of gain obtained

- $\langle G \rangle_{\max}$ = maximum possible mean gain value
- $\langle S_f \rangle$ = mean value of post-test (final)
- $\langle S_i \rangle$ = mean value of pre-test (initial)

The following table illustrates the categories of N-Gain values according to Hake (1999) presented in Table 8.

Table 8. N-Gain Score Category

| N-Gain Score Category | N-Gain Score Range |
|-----------------------|---------------------------------------|
| High | $\langle g \rangle > 0,7$ |
| Medium | $0,7 \geq \langle g \rangle \geq 0,3$ |
| Low | $\langle g \rangle < 0,3$ |

RESULT AND DISCUSSION

Result

This study aims to examine the effectiveness of using TikTok-assisted learning supplements to improve students' concept understanding ability and learning interest. This is based on previous research which shows that the low average score obtained indicates that students still find it difficult to understand mathematical concepts (Sipayung, 2018) and one of the factors that cause it is the low interest of students in learning mathematics subjects (Suendarti & Liberna, 2021).

Based on the results of research conducted by Aldi et al. (2022), Lasmiyati & Harta (2014), Safitri et al. (2020), dan Syaifuddin & Rahmasari (2023), showed that the use of various types of learning media, such as modules, videos, educational games, and animated films, can improve students' concept understanding and interest in learning mathematics. Thus, it appears that the use of learning media with social media is still small, especially in learning mathematics.

Therefore, the use of social media in this study is utilized as a means of learning mathematics that provides different values and motivation. The advantages of social media that are flexible and have an attractive appearance with a combination

of text, images and videos can captivate the interest of students. In fact, social media also allows triple communication between educators, students, and other students (Pujiono, 2021). This is based on previous research which shows that the use of social media, such as Whatsapp Group, can have a positive effect on Amalia & Puwaningsih (2020) concept understanding ability and social media, such as TikTok, can have a positive effect on students' interest in learning mathematics (Septiani & Abadi, 2022).

The social media used in this study is TikTok as a learning supplement. The reason for using TikTok as a social media used for learning supplement media is because the characteristics of the application are the use of videos with a short duration, around 15 to 60 seconds. This affects user behavior to continue accessing the application because it gives the impression of being hypnotized by the instant pleasure provided (Firamadhina & Krisnani, 2021).

TikTok is a popular social media platform that offers photo and short video sharing services with various multimedia features. Launched in September 2016 in China, TikTok has shown rapid growth globally, especially among millennials and generation Z. The use of TikTok as a learning supplement involves the use of social media as a learning supplement. Using TikTok as a learning supplement involves presenting learning information in short videos of 15 to 60 seconds, often with the use of background music, to increase concept understanding and learner interest.

In order to make the presentation of material on TikTok more interesting and effective as a learning medium, it needs to be packaged nicely using various features of the platform. Utilizing voiceovers, additional music, filters and hashtags can be the solution. The additional music element is TikTok's main attraction, allowing

educators or users to create video content with music that suits the audience's learning style. The voiceover feature is equally important, allowing the recording duration to be adjusted to match the video duration. On the other hand, hashtags help students find interesting videos based on their interests, and filters can be used to enhance the visual appeal of videos.

The effectiveness of using TikTok-assisted learning supplements is evidenced by the significant difference and increase in the average value of N-Gain (normalized gain) of students' concept understanding ability in the experimental class which is significantly better than the control class. In addition, the use of TikTok-assisted learning supplements is said to be effective if there is a significant difference and an increase in the average value of N-Gain (normalized gain) of students' learning interest in the experimental class is significantly better than the control class.

Normality Test

The normal distribution of the data was tested using the Normality Test. Given the large amount of data (>30), the data of this study was considered typical and did not require further testing. This opinion is supported by the concept of central limit which states that for a large sample, the distribution of the sample mean \bar{X} will approach the normal distribution (Healey, 2010). Thus, it can be concluded that the Normality test in this study has been fulfilled.

Homogeneity Test

The homogeneity of samples from the same population was verified using the homogeneity test. In this study, the homogeneity of variance test with Levene Statistic was run through the IBM SPSS Statistics 25 for Windows application.

Homogeneity test results of students' concept understanding ability test data in experimental and control classes are presented in Table 9.

Table 9. Results of Homogeneity Test of Students' Concept Understanding Ability Test in Experimental and Control Classes

| | | Levene Statistic | df1 | df2 | Sig. |
|--|--------------------------------------|------------------|-----|--------|------|
| Hasil Tes Kemampuan Pemahaman Konsep Peserta Didik | Based on Mean | .138 | 1 | 63 | .711 |
| | Based on Median | .029 | 1 | 63 | .865 |
| | Based on Median and with adjusted df | .029 | 1 | 62.703 | .865 |
| | Based on trimmed mean | .164 | 1 | 63 | .687 |

Source: Primary Data Calculation Results

Levene Statistic analysis shows a significant Sig value on the student concept understanding ability test data, both in the experimental and control classes. This indicates that the variance of the post-test data of the two groups (experimental and control classes) is homogeneous, with a Mean value (0.711) which is greater than 0.05. In conclusion, there is no significant difference in the variance of post-test data between the two groups (homogeneous).

Homogeneity test results of student interest questionnaire data based on pre-test and post-test in experimental and control classes are presented in Table 10. Table 11. Results of Homogeneity Test of Student Learning Interest Questionnaire in Experimental Classes and Control Classes

Table 10. Independent Sample T-Test of Students' Concept Understanding Ability

| | | Levene's Test for Equality of Variance | | t-test for Equality of Means | | | | 95% Confidence Interval of the Difference | | |
|--------------------------------------|-----------------------------|--|------|------------------------------|--------|-----------------|-----------------|---|-------|-------|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Hasil Tes Kemampuan Pemahaman Konsep | Equal Variances assumed | .138 | .711 | 5.198 | 63 | .000 | 5.364 | 1.032 | 3.302 | 7.426 |
| | Equal variances not assumed | | | 5.190 | 61.957 | .000 | 5.364 | 1.033 | 3.298 | 7.429 |

Source: Primary Data Calculation Results

| | | Levene Statistic | df1 | df2 | Sig. |
|---|--------------------------------------|------------------|-----|--------|------|
| Hasil Kuesioner Minat Belajar Peserta Didik | Based on Mean | .072 | 1 | 63 | .790 |
| | Based on Median | .069 | 1 | 63 | .793 |
| | Based on Median and with adjusted df | .069 | 1 | 59.675 | .793 |
| | Based on trimmed mean | .072 | 1 | 63 | .789 |

Source: Primary Data Calculation Results

Analysis of student interest data with Levene Statistic shows an insignificant Sig significance value (0.790 > 0.05). This shows that the variance of student interest data in the experimental class and control class is not significantly different (homogeneous).

Independent Sample T-Test

Based on the assumption that both groups have homogeneous characteristics and follow a normal distribution pattern, this study used the Independent Sample T-Test to analyze whether there is a significant difference between the two groups based on the data collected.

The use of IBM SPSS Statistics 25 for Windows resulted in an Independent Sample T-Test analysis of student concept understanding ability test data, the results of which are listed in Table 11.

The "Independent Samples Test" table shows the variation in students' concept understanding test scores with a

significance value ($0.000 < 0.05$ (2-tailed), confirming the significant difference between the two groups. This indicates that there is no significant difference in the mean scores of concepts understanding capacity between students who used the TikTok-assisted learning supplement and those who did not. Therefore, considering the considerable difference, it can be concluded that the use of TikTok-assisted learning supplement did not show any visible benefit in students' concept understanding of arithmetic series and sequence material.

The findings of the Independent Sample T-Test on the student interest questionnaire data are presented in Table 12. Data analysis was conducted using IBM SPSS Statistics 25 software Windows version.

Based on the "Independent Samples Test" table which measures the variation in the findings of the student interest questionnaire, it is known that the Sig value. (2-tailed) value of (0.377) is greater than 0.05. This indicates that there is no significant difference between the two groups. In conclusion, there is no significant difference between the mean scores of students' interest in learning who use TikTok-assisted learning supplements and those who do not. The absence of this substantial difference indicates that the use of TikTok-assisted learning supplements does not have a significant effect in increasing students' interest in learning arithmetic sequence.

N-Gain Score

Table 12. Independent Sample T-Test Test of Students' Learning Interests

| | | Levene's Test for Equality of Variance | | t-test for Equality of Means | | | | | 95% Confidence Interval of the Difference | |
|---|-----------------------------|--|------|------------------------------|--------|-----------------|-----------------|-----------------------|---|-------|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Hasil Kuesioner Minat Belajar Peserta Didik | Equal variances assumed | .072 | .790 | -.890 | 63 | .377 | -.2.132 | 2.395 | -6.918 | 2.654 |
| | Equal variances not assumed | | | -.892 | 62.513 | .376 | -2.132 | 2.391 | -6.909 | 2.646 |

Source: Primary Data Calculation Results

Table 13. N-Gain Score Test of Students' Concept Understanding Ability

| | | Descriptives | | | | | | | | | | | |
|--------------|---------------------------|-----------------|---------------------|-----------------|-----------|------------|---------------|-----------|---------|-------------|-------------|-----------|------------|
| | | Statistic | | | | | Std. Error | | | | | | |
| Kelas | Statistic | Mean | Lower Bound | Upper Bound | Inter-Val | Std. Error | Kelas | Statistic | Mean | Lower Bound | Upper Bound | Inter-Val | Std. Error |
| NGain_Persen | Pertanyaan Tes Eksperimen | Mean | 65.8335 | 56.8626 | 74.8044 | 4.39854 | Kelas Kontrol | Mean | 38.5030 | 31.1961 | 45.8098 | 3.58718 | |
| | 95% Confidence Interval | 5% Trimmed Mean | 66.5676 | 5% Trimmed Mean | 38.5996 | | | | | | | | |
| | Median | 64.9123 | Median | 27.7778 | | | | | | | | | |
| | Variance | 619.109 | Variance | 424.640 | | | | | | | | | |
| | Std. Deviation | 24.88189 | Std. Deviation | 20.60681 | | | | | | | | | |
| | Minimum | 16.67 | Minimum | 5.26 | | | | | | | | | |
| | Maximum | 100.00 | Maximum | 68.75 | | | | | | | | | |
| | Range | 83.33 | Range | 63.49 | | | | | | | | | |
| | Interquartile Range | 46.95 | Interquartile Range | 37.87 | | | | | | | | | |
| | Skewness | -.086 | .414 | Skewness | .170 | .409 | | | | | | | |
| | Kurtosis | -.960 | .809 | Kurtosis | -1.557 | .798 | | | | | | | |

The N-Gain Score test is used to determine the increase in concept understanding ability and students' interest in learning after being given treatment in the form of using learning supplements assisted by TikTok in the experimental class. This method involves the implementation of pre-test and post-test in experimental and control classes.

The following is a table of the results of the N-Gain Score test analysis of students' concept understanding ability test data using the IBM SPSS Statistics 25 for Windows program presented in Table 13.

The "Descriptives" table above shows some important findings, namely 1) The average value of N-Gain Score for the experimental class (with TikTok-assisted learning supplement) is 0.658335, which is categorized as "medium"; and 2) The average value of N-Gain Score for the control class (without TikTok-assisted learning supplement) is 0.385030, which is

also categorized as "medium". The use of TikTok-assisted learning supplements in teaching mathematics is proven to be effective in helping students understand the concept of arithmetic series and sequence with a simple category. This is evidenced by the achievement of better understanding in students who used the supplement compared to those who did not.

The N-Gain Score test analysis for student interest questionnaire data was conducted using IBM SPSS Statistics 25 for Windows software, and the results are presented in Table 14 below.

Based on the descriptive analysis in the table, several important findings were obtained, namely 1) The average N-Gain Score value for the experimental class (which used TikTok-assisted learning supplements) was 0.130531. This value is included in the "low" category; and 2) On the other hand, the average N-Gain Score for the control class (which did not use TikTok-assisted learning supplement)

Table 14. N-Gain Score Test of Students' Learning Interest

| Descriptives | | | | | |
|-------------------------|---------------------------------|-------------------------|------------------------------|------------|---------|
| Kelas | | | Statistic | Std. Error | |
| NGain_Persen | Pernyataan Kuesioner Eksperimen | Mean | 13.0531 | 1.84936 | |
| | | 95% Confidence Interval | Lower Bound | 9.2813 | |
| | | | Upper Bound | 16.8249 | |
| | | 5% Trimmed Mean | 12.7001 | | |
| | | Median | 10.1010 | | |
| | | Variance | 109.445 | | |
| | | Std. Deviation | 10.46158 | | |
| | | Minimum | .00 | | |
| | | Maximum | 32.69 | | |
| | | Range | 32.69 | | |
| | | Interquartile Range | 15.31 | | |
| | | Skewness | .672 | .414 | |
| | | Kurtosis | -.905 | .809 | |
| | | NGain_Persen | Pernyataan Kuesioner Kontrol | Mean | 10.7680 |
| 95% Confidence Interval | Lower Bound | | | 7.7768 | |
| | Upper Bound | | | 13.7592 | |
| 5% Trimmed Mean | 10.2603 | | | | |
| Median | 10.0000 | | | | |
| Variance | 71.163 | | | | |
| Std. Deviation | 8.43585 | | | | |
| Minimum | .00 | | | | |
| Maximum | 31.11 | | | | |
| Range | 31.11 | | | | |
| Interquartile Range | 13.69 | | | | |
| Skewness | .773 | | | .409 | |
| Kurtosis | .035 | | | .798 | |

Source: Primary Data Calculation Results

was 0.107680. This value is also included in the "low" category. So it can be concluded that mathematics learning both using and not using TikTok-assisted learning supplements is not effective for increasing students' learning interest in the material of arithmetic rows and series with a low category.

Discussion

Concept Understanding Ability

The effectiveness of TikTok-assisted learning supplements to improve students' conceptual understanding is measured using the N-Gain value, as shown by the research results. Both the control group and the experimental group obtained N-Gain values that were classified as moderate. The N-Gain value is categorized into three levels, namely high (more than 0.7), medium (between 0.3 and 0.7), and low (less than 0.3). Indicators used in the test of students' concept understanding ability include restating a concept; classifying objects according to certain properties (in accordance with the concept); providing examples and non-examples of a concept; presenting concepts in various forms of mathematical representation; developing necessary or sufficient conditions for a concept; using, utilizing, and selecting certain procedures or operations; and applying concepts or problem solving algorithms.

The results of data analysis showed significant differences between the two groups (Sig. (2-tailed) ($0.000 < 0.05$), so the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted. This is evidenced by the higher average N-Gain Score in the experimental group (0.658335) compared to the control group (0.385030). In conclusion, the use of TikTok-assisted learning supplements in classroom teaching proved effective in helping students understand the concept

of arithmetic sequence. This is supported by the activities and involvement of students during learning by using TikTok-assisted learning supplements presented for each learning syntax so as to improve their concept understanding abilities and learning achievement.

Thus, based on the results of research and data analysis, it is obtained that the use of TikTok-assisted learning supplements is effective for improving students' concept understanding abilities on arithmetic series and sequence material. These results are inseparable from various activities in the learning process that have a positive impact on improving students' learning achievement. TikTok-assisted learning supplements are used by utilizing its characteristics, namely the short duration of the video and automatically replaying the video so that it makes students seem hypnotized by the video. In addition, the addition of background music (background) makes students not feel bored and continue to scroll through the learning supplement content that has been created.

In addition, the addition of text to the TikTok video helps learners focus more on understanding the content of the learning supplement video content because the text displayed is adjusted to the speed of the researcher's voice when speaking so that learners will pay more attention to the text if the surrounding conditions are noisy and do not have good hearing aids such as earphones or the like.

Thus, the use of TikTok-assisted learning supplements is able to be in the moderate category to improve students' concept understanding abilities when the content created is not boring by making short videos, adding background and text to the video. This finding is in line with Firamadhina & Krisnani (2021) who state that the use of social media such as TikTok in the realm of education can provide

benefits and positive impacts, especially if used with positive purposes such as disseminating information or exploring new knowledge intentionally or unintentionally. This is in line with the results of research conducted by Pratama et al. (2020) which shows that the use of learning video media as a learning supplement is effective in improving students' understanding of learning materials. In addition, using TikTok-assisted learning supplements of the audio-visual type, according to Adam (2023) states that the use of audio-visual learning media in the learning process can stimulate students' interest in learning.

In addition, based on factors that can affect students' concept understanding abilities according to Ngalim (2007), namely individual factors and social factors. One of the individual factors related to students' interest in learning is personal motivation. According to Fazri (2023), a lack of motivation in learners can affect concept understanding and reduce their interest in learning and learning outcomes, while creative and innovative educators are able to make math learning more fun, interesting, and liked by students without feeling boring. On the other hand, social factors that can affect learners' concept understanding ability related to learners' interest in learning are the influence of educators and teaching methods, availability of tools, learning environment and available opportunities, and social motivation from the surrounding environment. Where these are also external factors that can affect the learning process.

By using TikTok-assisted learning supplements to implement ways that can be done to increase students' interest in learning according to Slameto (2015), namely creating a democratic atmosphere and using tests and assessments wisely, what is done in creating a democratic atmosphere is to provide

independent learning opportunities, encourage discussion, and develop students' thinking, problem-solving, and curiosity skills. In addition, tests and assessments are only carried out at the beginning and end of learning. However, individual assignments are still given to develop learners' thinking and problem-solving skills. Thus, based on factors that can influence learners' concept understanding, such as personal motivation and environmental influences, creative and innovative learning approaches and a democratic atmosphere can strengthen their interest in learning. The use of TikTok-assisted learning supplements can facilitate a democratic atmosphere by providing independent learning opportunities, stimulating discussion, and enriching learners' thinking and problem-solving skills, along with a thoughtful evaluation approach in the application of tests and assessments.

Learning Interest

Both in the experimental and control groups, the results showed that the N-Gain value used to assess the effect of TikTok-assisted learning supplements on student learning motivation was low. N-Gain is categorized into three levels, namely high (value > 0.7), medium (value between 0.3 and 0.7), and low (value < 0.3). Indicators used in the learner interest questionnaire include feelings of pleasure, learner involvement, learner attention, and learner interest.

Based on the data analysis of the students' interest questionnaire, no significant difference was found between the two groups. This is evidenced by the Sig. (2-tailed) (0.377) which is greater than 0.05. These results indicate acceptance of the null hypothesis (H_0) and rejection of the alternative hypothesis (H_a). In the experimental class, the average value of N-Gain Score was 0.130531 (low category),

while in the control class it was 0.107680 (low category), based on the N-Gain Score test. Thus, the use of TikTok-assisted learning supplements in arithmetic sequence material was not effective in increasing students' interest in learning. This is due to the characteristics of TikTok which is more suitable as an entertainment platform than a structured and focused learning resource.

The results showed that the use of TikTok-assisted learning supplements was not effective in increasing students' interest in arithmetic series and sequence. This conclusion is based on the findings and analysis of the data obtained. Although there was an increase in the average intensity of using TikTok as a learning supplement every day, it did not have a significant impact on increasing students' interest in learning.

In addition, based on the results of data analysis of students' learning interest questionnaires on the increase in the average value and N-Gain Score value of each indicator of students' learning interest in both groups, it was found that the use of TikTok-assisted learning supplements was not effective in increasing students' learning interest. The use of TikTok-assisted learning supplements is not effective for increasing students' feelings of pleasure. This can be seen from the attitude and behavior of discipline, paying attention to lessons, and repeating lessons of students in the experimental class which is not better than the control class.

In addition, the use of TikTok-assisted learning supplements is not effective in increasing learners' engagement. This can be seen from the attitudes and behaviors of happy to discuss in class, trying to answer questions from the educator, and the desire to increase students' reading resources in the experimental class which is not better than the control class.

In addition, the use of TikTok-assisted learning supplements was not effective in increasing learners' attention. This can be seen from the attitudes and behaviors of completing notebooks, always doing the exercises given, and being eager to take part in the lessons of students in the experimental class which are not better than the control class.

Finally, the use of TikTok-assisted learning supplements is not effective for increasing learners' interest. This can be seen from the attitudes and behaviors of participating in teaching and learning activities (KBM) in class, attitudes in difficulties, efforts in dealing with difficulties, and habits in following lessons of students in the experimental class which are not better than the control class.

Thus, based on the results of the data analysis of the students' learning interest questionnaire on the increase in the average value and the N-Gain Score value of each indicator of students' learning interest in both groups, it can be concluded that the use of TikTok-assisted learning supplements is not effective for increasing students' learning interest with a low category in each indicator of learning interest, namely 1) feelings of pleasure, 2) student involvement, 3) student attention, and 4) student interest.

The content of the songs in the TikTok-assisted learning supplement is not in accordance with the characteristics of the learners, which involves tones from songs such as "Balonku" and "Naik Kereta Api". This is not in accordance with the characteristics of learners based on various aspects, as described by Munawaroh (2021), such as interest and motivation. Interest, which is related to individual interests, plays an important role in the learning approach. Therefore, it is necessary to continuously develop materials according to learners' interests. Motivation, which is reflected in the quality of learners'

involvement, feelings, affective engagement, as well as learners' efforts to maintain motivation, also needs to be considered in developing learning content.

Thus, the use of TikTok-assisted learning supplements can be in the low category to increase learners' interest in learning when the content created is not in accordance with learner characteristics such as interest and motivation. This finding is in line with Meilana & Aslam (2022) who state that the content in the development of teaching materials needs to be adjusted to the characteristics of learners, even though each child has different characteristics. Educators need to understand the initial characteristics of learners to easily deal with everything related to learning, such as lesson composition, ability, and the choice of management strategies that affect the teaching in question. These components can be adjusted to the individual characteristics of learners so that they can affect the interest and motivation of learners to learn.

In addition, according to Fuad & Zuraini (2016, pp. 45–46), there are factors that can affect students' interest in learning such as internal factors and external factors. Internal factors such as psychological aspects include several factors that can affect learners' interest in learning, such as response, memory, and thinking (Sardiman A.M., 1990). These factors are related to the concept understanding ability of learners, where the attitude of learners in responding, solving, and thinking about questions given by educators after watching video shows on TikTok-assisted learning supplements does not show feelings of pleasure, involvement, attention, and interest from learners in answering questions orally.

On the other hand, external factors such as schools consist of various factors that can affect students' interest in learning, such as teaching methods, facilities

and infrastructure, learning resources, and learning media need to be considered (Fuad & Zuraini, 2016, pp. 45–46). These factors are also included in the factors that can affect students' concept understanding ability. Although during the learning process students are given the opportunity to be more interactive and involved, there is still a need for teaching methods, facilities and infrastructure, learning resources, and other learning media that can increase students' interest in learning. The use of TikTok-assisted learning supplements is not effective in increasing students' interest in learning because the factors that influence learning interest, both internal and external, show that teaching methods, facilities and infrastructure, learning resources, and learning media need to be considered as a whole, not just by utilizing one particular social media platform such as TikTok.

Implications

This study finds out the effectiveness of TikTok-assisted learning supplements to improve students' concept understanding ability and interest in learning on the material of arithmetic rows and series. By knowing the effectiveness, mathematics educators are expected to improve students' concept understanding ability and interest in learning using appropriate and effective social media in creating innovative and interesting learning. In addition, students are expected to use social media as a medium to find information or additional material not only for entertainment media to improve concept understanding ability, interest in learning and foster active learning.

This research provides and adds knowledge and insight into learning supplements assisted by social media, especially TikTok which can be used in learning mathematics to improve students'

concept understanding ability and interest in learning on the material of arithmetic rows and series. Therefore, for future researchers who are interested in conducting research on the effectiveness of a social media in the context of learning on the ability to understand concepts and students' interest in learning, they can use other social media and/or other cognitive aspects or affective aspects.

Limitations

This research is limited to the material of arithmetic rows and series. Therefore, the results of this study only discuss the concept understanding ability and learning interest of students related to this topic. In addition, the respondents used in this study were at the senior high school level in one district in Indonesia, so the results of this study do not represent the concept understanding ability and learning interest of students in other schools or junior high school levels. Nevertheless, the respondents involved came from a class that was carrying out the material of arithmetic rows and series, namely grade 11, so the results can be used as evidence of concept understanding and learning interest of grade 11 students at the school.

CONCLUSION

Based on the results of research conducted by researchers in class XI IPA 5 SMA Negeri 1 Manonjaya related to TikTok-assisted learning supplements to improve students' concept understanding ability and interest in learning, it is concluded that the application of TikTok-assisted learning supplements on the material of arithmetic rows and series shows promising results in improving students' concept understanding (cognitive) abilities. This is evidenced by the increase in the moderate category, with a percentage

value of 0.658335. However, in terms of increasing students' affective learning interest, this supplement has not shown significant effectiveness. The assessment results show a percentage value of 0.130531 with a low category, which indicates that the use of TikTok-assisted learning supplements is not effective enough to increase students' affective learning interest in the material.

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Development of Islamic boarding school-based learning tools on social arithmetic material to improve students' numeracy skills

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Abstract

The numeracy abilities of students in Indonesia are still considered inadequate or quite low and must continue to be improved. One of the efforts made to improve students' numeracy abilities is by implementing learning tools that can support the development of these abilities. The research aims to develop learning tools that can be declared valid, practical, and effective, especially in social arithmetic material, and improve students' numeracy skills. This research is development research with the 4D model from Thiagarajan. Thiagarajan's 4D stages include the definition, design, development, and deployment stages. The data collection techniques used are observation, questionnaires, and tests. The research results on developing Islamic boarding school-based learning tools are classified as valid, practical, and effective. The level of validity can be seen from the validation value: for the teaching module, it is 3.47; LKPD is 3.44; for the learning achievement test, it is 3.32; and the manual is 3.31 (maximum score 4), which is included in the valid category. The practicality value obtained from the students' activities was 90.7%, which was in the very good category; the implementation of learning was 3.56, which means high value; as well as the students' response questionnaire showed a positive value. The effectiveness value seen from the students' learning outcomes data was obtained at 87.0% classical completion. Not only that, but effectiveness can also be seen from the students' numeracy ability test, namely the results *pre-test*, which was an average of 34.87% increase in revenue *post-test* to 82.0%, which was then analyzed using the N-Gain test to obtain an average result of 0.73 which was included in the high category. Thus, Islamic boarding school-based learning tools on social arithmetic material can effectively be used to improve students' numeracy skills.

Keywords: Numeracy, social arithmetic, Islamic boarding school-based learning

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Abstrak

Kemampuan numerasi peserta didik di Indonesia masih tergolong kurang atau cukup rendah dan masih harus terus ditingkatkan. Salah satu upaya yang dilakukan untuk meningkatkan kemampuan numerasi peserta didik adalah dengan menerapkan perangkat pembelajaran yang dapat menunjang berkembangnya kemampuan tersebut. Adapun penelitian yang dilakukan ini memiliki tujuan untuk mengembangkan perangkat pembelajaran yang dapat dinyatakan valid, praktis, dan efektif, khususnya pada materi aritmatika sosial serta mampu meningkatkan kemampuan numerasi santri. Penelitian ini termasuk dalam jenis penelitian pengembangan dengan model 4D dari Thiagarajan. Tahapan 4D dari Thiagarajan mencakup tahap pendefinisian, perancangan, pengembangan, dan penyebaran. Teknik pengumpulan data yang digunakan adalah observasi, angket, dan tes. Hasil dari penelitian pengembangan perangkat pembelajaran berbasis pesantren tergolong ke dalam kriteria valid, praktis, dan efektif. Tingkat kevalidan dapat dilihat dari nilai validasi, untuk modul ajar sebesar 3,47; LKPD sebesar 3,44; tes hasil belajar sebesar 3,32; dan buku petunjuk sebesar 3,31 (skor maksimal 4) yang termasuk pada kategori valid. Nilai kepraktisan diperoleh dari aktivitas santri sebesar 90,7% yang masuk dalam kategori sangat baik, keterlaksanaan pembelajaran sebesar 3,56 yang berarti bernilai tinggi, serta angket respon santri yang menunjukkan nilai positif. Nilai keefektifan dilihat dari data hasil belajar santri diperoleh 87,0% tuntas secara klasikal. Tidak hanya itu, keefektifan dilihat dari tes kemampuan numerasi santri, yakni hasil pre-test yang semula rata-rata 34,87% meningkat pada hasil post-test menjadi 82,0%, yang kemudian dianalisis menggunakan uji N-Gain dengan memperoleh hasil rerata 0,73 yang masuk dalam kategori tinggi. Dengan demikian dapat disimpulkan bahwa perangkat pembelajaran berbasis pesantren pada materi aritmatika sosial sudah layak untuk digunakan dan terbukti efektif untuk meningkatkan kemampuan numerasi santri.

INTRODUCTION

Mathematical literacy (numeracy) skills are mathematical skills needed for learning in the 21st century. This ability allows a person to understand and calculate numbers, calculate time, calculate prices, and analyze data, which are essential everyday competencies. Numeracy literacy skills are needed in all aspects of life, both at home and in society. For example, when shopping, starting a business, planning an activity, etc., the information is usually expressed in numerical/numbers or graphic form (Mahmud & Pratiwi, 2019). Therefore, numeracy literacy is an important part of the skills or abilities that students must have.

Numeracy is the ability to think using procedural concepts, facts, and mathematical tools to solve everyday problems in various types of contexts that are relevant for individuals as Indonesian citizens and global citizens (Center for Assessment and Learning, 2020, McCallum, 2023). According to Singh *et al.* (2021), numeracy is a fundamental mathematical concept in everyday life that includes skills in counting, comparing and being able to differentiate, recognizing shapes and

positions, and solving problems (Via *et al.*, 2021). Numeracy includes the skill of applying mathematical concepts and rules in real everyday situations, where problems are often unstructured, and there are many ways to find complete solutions (GLN Team, Ministry of Education and Culture, 2017).

Although the numeracy results in Indonesia experienced an increase in rank, Indonesia's rank is still below the OECD average. Indonesia's PISA ranking position is ranked 69th out of 81 PISA participating countries with a score of 366 (OECD., 2022). This indicates that many Indonesian students still struggle with situations requiring problem-solving skills using mathematics (Puspendik, 2019). One of the factors causing low numeracy literacy skills in Indonesia, according to Fuadi *et al.* (2020), is due to low numeracy literacy skills, namely learning that is not contextual, meaning that the emphasis on understanding basic concepts and basic understanding of science is not linked to matters related to everyday life. If you want to improve students' numeracy skills, students should be used to solve problems related to everyday life.

Not only focused on the existing

PISA results, based on the results of the pre-test that was carried out at the Mujadi Education Unit (SPM) Wustha Al-Amiriyah Banyuwangi, it was found that the average numeracy ability of students at the Mujadi Education Unit (SPM) Wustha Al-Amiriyah Banyuwangi was classified as requiring special intervention. After the publication of Minister of Religion Regulation (PMA) No. 18 of 2014, the Mujadi Education Unit is an official education program under the Directorate of Early Education and Islamic Boarding Schools of the Indonesian Ministry of Religion. This is equated with Madrasah Tsanawiyah and "Aliyah" education, which is under the Directorate of Madrasah and Islamic Religious Education of the Indonesian Ministry of Religion. Islamic boarding schools can independently plan to develop the competencies of their students while still receiving a recognized diploma.

One of the reasons for the need for special intervention at the Wustha Al-Amiriyah Banyuwangi Mujadi Education Unit (SPM) is that the learning tools that are prepared are only adapted to student characteristics and learning outcomes, where mastery of existing basic literacy has not yet been developed, especially mathematical literacy. In general, to make learning more focused and meaningful, teachers use learning tools as a form of preparation before starting the learning process (Syamsiyah, 2015). According to the Decree of the Minister of Education and Culture No. 56 of 2022 concerning Guidelines for Implementing Curriculum in the Context of Learning Recovery, teaching tools are various teaching materials used by educators to achieve the Pancasila student profile and learning outcomes.

Based on the problem explained, it is necessary to have learning tools that can facilitate students in learning and

improving numeracy skills in mathematics. This is because later, the learning tools will be adapted to current learning, where teachers must carry out more learning activities that lead to student involvement and participation in and outside of class (Angraini et al., 2021, Kooloos et al., 2023). The learning tools in question consist of Teaching Modules, Student Worksheets (LKPD), and numeracy skills questions. Using everyday life contexts helps students learn abstract mathematical concepts through representation, thereby increasing students' motivation to study mathematics (Putri & Zulkardi, 2020). In line with this, the concept of social arithmetic is widely applied in everyday life (Satiti et al., 2021). Therefore, the learning tools that will be prepared will use mathematical problems from the Islamic boarding school context, which is suitable for learning social arithmetic (Muslimin et al., 2020).

Previous research related to the development of Islamic boarding school-based learning tools was carried out by Azhari and Mohammad Nadzir (2022). The research related to numeracy skills was conducted by Putri et al. (2022) entitled Development of Learning Tools Based on Lesson Study for Learning Communities with Cultural Values Using to Improve numeracy. The novelty of this research is that the researchers optimized the learning process by developing Islamic boarding school-based learning tools to create a conducive learning atmosphere by taking advantage of the students' habits or daily lives to improve the students' numeracy skills. Therefore, researchers are interested in conducting research titled **"Development of Islamic Boarding School-Based Learning Tools on Social Arithmetic Material to Improve Santri Numeracy Skills."**

METHOD

This research aims to create learning tools that include teaching modules, device user manuals, student worksheets, and test packages that are valid, practical, and effective. Therefore, this research is classified as development research that uses the 4D development model. The 4D model was chosen because of some reason. First, the stages used in the 4D model

are more detailed and systematic, making the development process more manageable. Second, it involves experts' judgment in determining the final quality of a product being developed (learning tools) to guarantee that the prototype is constructed consistently based on the theory. Third, a defined stage is targeted to reflect or review the real needs based on the students' or learners' perspectives. The 4D

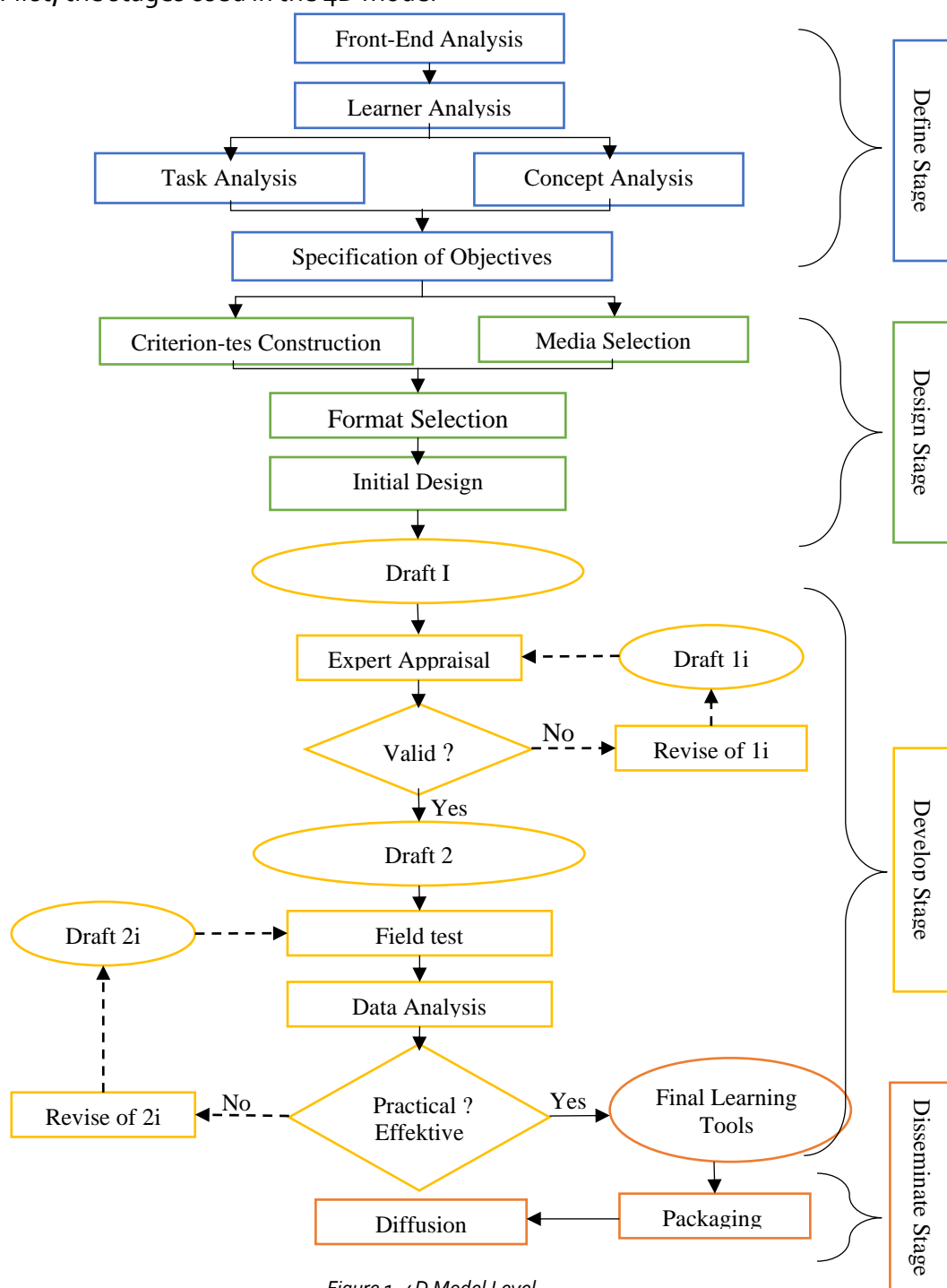


Figure 1. 4D Model Level

stages are presented in Figure 1.

The definition stage is the first step in determining the terms or needs of learning. The design stage aims to compile the learning device until it becomes a prototype. The development stage aims to produce *draft* one learning tools, then *draft 1*. These are validated by experts and improved based on expert input and suggestions, which will then produce results *in draft two*, which is valid and ready to be carried out in the field trials; in the field trial process, there are two stages, namely small group trials in this stage to determine the readability of the learning tools and large group trials carried out to determine the practicality of the learning tools. The final process is the dissemination stage, which distributes the results of learning tools declared valid, practical, and effective within a broader range.

The testing area in this research was the Mujadi Wustha Al-Amiriyyah Banyuwangi Education Unit, with the sample for small group testing (readability test) being six students from class VIII and the large group testing sample consisting of 23 students from class VIIC. As for activities *pre-test* and *post-test* were given to analyze the increase in students' numeracy skills before and after participating in learning activities with Islamic boarding school-based learning tools. The practicality and effectiveness of data analysis will be carried out after the trial is complete.

This data's validity is analyzed to ensure that the learning tools and research instruments function properly. Next, the validation data is analyzed by summarizing the assessment data for each validator, calculating the average value of the validator results for each indicator, calculating the average value for each aspect, and calculating the total average value for all aspects (V_a). Then, learning tools and research instruments are declared valid if

their validity score obtains a minimum average score of 3 for each validation item (maximum score of 4) (Hobri, 2021).

Data analysis related to practicality (easily to use) refers to the results of data that has been collected from the observation sheet on the implementation of the learning tool plan and then analyzed to see the practicality of the learning tool, namely by recapitulating the results of the observations, determining the average value of the observation results for each indicator, calculating the average value for each aspect. Observations and calculate the total average value from the average value for all aspects (I_0). Learning tools are declared practical if they obtain high criteria results with a minimum score of 3 for each aspect (maximum score of 4) (Hobri, 2021). Then, the device is said to be practical if the category of student activity observation that is met is at least good, and the number of students who answer in the affirmative, which is expressed as a positive response to each aspect, is more than equal to 80%.

Data analysis to effectiveness criteria can be seen from the test of learning outcomes and improvement of students' numeracy skills. The device is categorized as effective when the learning result test data is more than 70% of the total number of santri who complete classical with minimum completeness criteria 70, and the increase in the numeracy ability of santri in the N-Gain category of moderate numeracy ability is more than 70%.

The increase in students' numeracy abilities was measured from the numeracy ability learning outcomes test, which was then analyzed using N-Gain. The N-Gain formula is as follows.

$$g = \frac{St - Si}{Sm - Si} \times 100\%$$

Information : g = N-Gain percentage | St = score post-test
| Si = score pre-test | Sm = maximum score

RESULTS AND DISCUSSION

Results

Below, we will describe the process and results of developing Islamic boarding school-based mathematics learning tools using the PBL model to improve the numeracy skills of students using the 4D model, which includes the stages of definition, design, development, and dissemination.

Definition stage (define)

This stage consists of beginning-to-end analysis, student analysis, concept analysis, task analysis, and specification of learning objectives. Based on the initial and final activities, it was found that the existing problems were learning tools that needed to be more optimal for students to develop numeracy skills, learning resources still depended on textbooks, and learning methods were monotonous using lectures and assignments. Then, from the student analysis activities, it was found that the average data on the numeracy abilities of class VII students was still relatively low. The age range for class VII students is between 12 and 13 years, according to Jonh Piaget (Kamila *et al.*, 2022, Hakkarainen *et al.*, 2023); these students are already at the formal operational stage. Therefore, they can participate in the problem-solving process in class (Tarmizi & Bayat, 2019).

Then, concept analysis was carried out to identify the material content related to social arithmetic. This material is adapted to the Merdeka Curriculum, namely the Number Element, concerning taxes, profits, and discounts. This analysis can be in the form of tasks that lead to numeracy skills so that achievement indicators are maximized. Next, the learning objectives and outcome specifications in Phase D of the curriculum used in this

learning tool will be determined.

Planning stage (design)

Activities at this stage include test preparation, media selection, format selection, and initial design. At the test preparation stage, numeracy test questions are prepared and arranged in the form of essay questions consisting of 3 questions and referring to numeracy indicators. This activity begins with making a test grid with alternative answers and scoring guidelines oriented toward numerical indicators. Media selection is carried out to assist in presenting learning material. The media used are whiteboards and LKPD, prepared based on the Problem-Based Learning (PBL) model. The function of the whiteboard media is to help students be actively involved in writing down and explaining the solutions they obtain during presentation activities. The choice of format is aligned with the Islamic boarding school-based learning model. The final step at the design stage is to design all learning devices, including teaching modules, device use manuals, Student Worksheets (LKPD), and learning outcomes tests.

The first design is a teaching module, which consists of 3 meetings. The teaching modules that will be developed refer to the Merdeka curriculum. Teaching modules are essential in supporting teachers in planning learning (Nesri & Kristanto, 2020, Rufii, 2015). There is a cover and three main components in the teaching module. The main components are school identity, initial competencies, Pancasila student profile (P3), facilities and infrastructure, target students, and learning models used. The main components of learning include learning objectives, meaningful understanding, trigger questions, learning preparation, learning activities, assessment, enrichment,

fremedial, and teacher and student reflection. In addition, attachments include LKPD, teacher and student reading materials, a glossary, and a bibliography (Maulida, 2022).

Then, the second plan is in the form of a device usage instruction book, which has a cover, PBL syntax, numeration indicators, and procedures to implement PBL model learning from the beginning to the end; this is arranged to help teachers create a learning process that matches the stages in the teaching module and aims to improve students' numeracy skills. According to Indrawati (2021), the instruction book provides information and guidance for the reader to carry out activities according to the instructions.

The third design is the Student Worksheets (LKPD) design, which consists of three LKPDs, which include the cover, student identity, learning objectives, problem presentation, *scaffolding*, solutions, and conclusions from problem-solving (Safitri & Arnawa, 2019). There are three subjects used, namely taxes, profits, and discounts. The development of this LKPD can facilitate and make it easier for students to follow the learning process in class to create effective interaction between students (Piper et al., 2018). The existence of an exciting worksheet that meets the learning criteria must be there to stimulate student activity and train students' psychomotor skills and skills in the learning process in class (Maharani & Sari, 2024).

The fourth design is a learning outcomes test, which consists of a grid for preparing a numeracy test, a set of questions containing all the statement items in the test, a scoring rubric, and a question-answer key. The test preparation grid is also adjusted to the Learning Outcomes in social arithmetic material. The test questions developed are contextual questions that are close to students, such as habits

often carried out by students, characteristics of Islamic boarding schools, and so on. Tests are designed to measure students' qualities, abilities, skills, or knowledge against given standards, with a final assessment of whether they are acceptable (Indahri, 2021). When the test questions are relevant to the student's experience, knowledge, and interests, they will be more involved in measuring numeracy abilities more accurately. This learning outcomes test is used to analyze the device's effectiveness in terms of performance *pre-test* and *post-test*.

Development stage (develop)

At this stage, the teaching modules, device user manuals, LKPD, and learning outcomes tests are validated by experts who then carry out assessments and provide suggestions for revision so that later field trials can be carried out. Validation results can be seen in Table 1.

Table 1. Validation results of learning tools

| Learning media | Va | Category |
|---------------------------|------|----------|
| teaching modules | 3,47 | Valid |
| Devise user manuals | 3,31 | Valid |
| Student Worksheets (LKPD) | 3,44 | Valid |
| learning outcomes tests | 3,32 | Valid |

Based on Table 1. The validation results of the four Islamic boarding school-based learning tools are in the score interval $3 \leq \text{And} < 4$ is categorized as valid. The conclusion is that the learning tool is declared valid.

Then, the development stage aims to analyze the practicality and effectiveness of the device. Student Worksheets (LKPD) and valid learning results tests, then a small group trial (readability test) was carried out in class VIII with the subject of 6 students whom the teacher had selected to determine readability; the

result was that there were no words or sentences that needed to be revised again. Then, the device was tested in the field, namely in class VIIC, for three meetings, and students were asked to work on test questions at the beginning and end of the meeting. Before starting learning, the teacher reads the user manual first so that learning can begin at the stages of creating the teaching module, which aims to improve students' numeracy skills. Then, follow the stages according to the teaching module that uses the PBL learning model (Fauziyah et al., 2021).

At the first meeting, students were given a *pre-test*, which lasted 40 minutes. Then, the teacher starts the lesson by asking questions and daily problems so that the teacher can find out the students' problem-solving abilities, which will later be used to measure numeracy abilities. It is in line with the opinion that numeracy ability is a skill acquired in solving everyday problems (Mahmud & Pratiwi, 2019).

The next activity is to form groups of 4-5 students and continue distributing LKPD. Based on the results of observations, students' numeracy abilities emerged during the solving process, namely in the third PBL step. The first indicator that appears is applying various kinds of numbers and symbols related to basic mathematics to solve practical problems in various contexts of daily life. Students use evidence when solving problems listed on the LKPD and express reasons for solving the problem. The following is picture 2—examples of problems on the student sheet.

When writing down the concepts that will be used, the students are still confused because they do not know the meaning of the concepts used, so the teacher gives them *scaffolding* to the students to produce the second indicator, namely, the students carry out an analysis of the explanations presented in various

forms. This was confirmed by Yuliawanti et al. (2019) with the use of *scaffolding*. In problem-based learning activities, students' ability to solve problems is hoped to increase.

LKPD 1 TAX

Before starting the lesson form groups consisting of 4-5 students

Problem 1

Mr. Syafii is a civil servant who has a monthly bisyaroh of IDR 8,000,000.00. The income tax he must pay is 5% of his total bisyaroh. Apart from that, as a Muslim, Mr. Syafii also pays professional zakat of 2.5% of his bisyaroh, so how much clean bisyaroh does Mr. Syafii get per month?

Scaffolding

Use the following help to solve the above problem.

Professional Charity = $2.5\% \times \text{Income}$
 Income Tax = $5\% \times \text{Income}$
 Net Income Results = $\text{Wages} - \text{Zakat} - \text{Income}$

LKPD ARITMATIKA SOSIAL 1

Solution

> Is known:
 1 Month's salary =
 1 Year salary =

> Asked: Monthly Net Salary?
 > Answer:
 Concept Used:
 a. Income Tax
 b. Professional Charity

> 1 Month zakat = $\frac{2.5}{100} \times \text{Rp}8.000.000.00 = \dots\dots\dots$
 > 1 Month's Income = $\frac{5}{100} \times \text{Rp}8.000.000 = \dots\dots\dots$
 > Net Salary =
 > So, the clean bisyaroh that Mr. Syafii gets per month is.....

Put a tick in the column regarding the correct conclusion regarding taxes and professional zakat!

PPh is an abbreviation of income tax
 Professional zakat is not mandatory
 Income tax law is mandatory
 The professional zakat ratio is 85 grams of gold
 Income Tax is only for rich people
 The profeszi zakat rate is 2.5%

LKPD ARITMATIKA SOSIAL 3

Figure 2. Problems that exist on students' worksheets

During the step of developing and presenting the results of their work, the students make a presentation by bringing up the third indicator, namely Interpreting the results of the analysis to predict and make decisions; they explain the conclusions of the problems that have been solved, the students also evaluate the problem-solving process, actively discuss and ask questions between groups. In line with the opinion of Naja et al. (2022), the PBL model can help students interact with each other and work together to achieve group success. As a result, using this learning tool will help students master the material, solve problems, and improve their numeracy skills.

Next, the results of the practical analysis were carried out on the students' activities and learning tools, which were tested by observing the implementation of learning and observing the students' activities. The results of the practicality test can be seen in Table 2.

Table 2. Results of observations of student activities and implementation of learning

| Results of observations | Meeting to- | | |
|----------------------------|-------------|------|-------|
| | 1 | 2 | 3 |
| student activities | 89,5% | 91% | 91,5% |
| implementation of learning | 3,25 | 3,58 | 3,83 |

The results of observations of student activities, the implementation of learning tools, and student response questionnaires were used as references for data analysis related to the practicality of the equipment. The average result of observing student activities was 90.7%, included in the very good category. The average result of observing the implementation of learning tools is 3.56, which is classified as high. The results of the student questionnaire responses were positive because more than 92% of the students answered "Agree" to each question asked. Thus, the teaching tools that have

been prepared can be practical based on this data.

The following analysis determines the effectiveness criteria based on learning outcomes data and students' numeracy abilities. The first indicator related to learning outcomes data showed that 19 out of 23 students had a mean of 82.1 and a classical completion percentage of 87.0%. The second indicator is related to students' numeracy abilities, which can be seen from the increase in N-Gain. The average N-Gain is 0.73, which is included in the high category. Thus, the learning tools that have been prepared can also be effective based on this data. Here is picture 3. Questions and answer keys for the numeracy test.

| NO | Question | Answer Key |
|----|---|---|
| 1 | Financial management implemented by Ust. Umar every month is as follows, he sets aside 2.5% of his <i>bisyaah</i> to pay zakat. The rest he always gives 5% of his <i>bisyaah</i> after deducting zakat. This month he wants to give prayer for the construction of a mosque. If Ust. Umar's <i>bisyaah</i> this month is IDR 4,000,000.00, how much money will Ust give prayer for? Umar for the construction of the mosque? | Is known: Zakat = 2.5% of salary Shodaqoh = 5% of salary minus zakat Salary = 4,000,000 Asked: how much money did Ust give shodaqoh? Alms for the construction of a mosque? Answer: Zakat = x 4,000,000 = 100,000 Shodaqoh = (salary - zakat) x 5% = (4,000,000 - 100,000) x = 3,900,000 x = 195,000 So the money donated by Ust. Umar for the construction of the mosque was 195,000 |
| 2 | Kang Zaid is a <i>santri</i> who is tasked with managing a cooperative owned by an Islamic boarding school. At the beginning of its opening, the cooperative managed by Kang Zaid used capital of Rp. 50,000,000 after one year, the cooperative managed by Kang Zaid issued zakat of IDR 2,450,000. How much profit does the cooperative managed by Kang Zaid make for a year? | Is known: Capital = 50,000,000 Trade zakat = 2.5% = 2,450,000 Has reached 1 haul (1 year) Asked: How much profit does the cooperative managed by Kang Zaid make for a year? Answer: Trade zakat = 2.5% of all trade property (capital + profit) Profit = zakat - 2.5% - capital = 2,450,000 - 50,000,000 = 98,000,000 - 50,000,000 = 48,000,000 So the cooperative's profit for 1 year is IDR 48,000,000 |

Working Instructions

1. Pray first before taking the following test questions.
2. Write your identity in the column provided
3. Work individually and read the questions carefully before doing them
4. Answer the questions as coherently and completely as possible on the answer sheet provided
5. Submit your answers to the teacher

QUESTION

1. The financial management implemented by Ust. Umar every month is as follows, he sets aside 2.5% of his *bisyaah* to pay zakat. The rest he always gives 5% of his *bisyaah* after deducting zakat. This month he wants to give alms for the construction of a mosque. If Ust. Umar's *bisyaah* this month is IDR 4,000,000.00, how much money will Ust. Umar for the construction of the mosque?
2. Kang Zaid is a *santri* who is tasked with managing a cooperative owned by an Islamic boarding school. At the beginning of its opening, the cooperative managed by Kang Zaid used capital of Rp. 50,000,000 after one year, the cooperative managed by Kang Zaid issued zakat of IDR 2,450,000. How much profit does the cooperative managed by Kang Zaid make for a year?



Figure 3. Questions and answer keys for the numeracy test

Deployment stages (*Disseminate*)

Mathematics learning tools are distributed offline, namely at the Mujadi Wustha Al-Amiriyyah Banyuwangi Education Unit, online, namely social media, which includes Instagram, WhatsApp, Facebook, and Islamic boarding school communication forums by providing a Google Drive link which contains all the tools so that the learning tools can be accessed by other teachers. Apart from that, this learning device also has intellectual property rights.

Discussion

The results of development research carried out in class VIIC of the Mujadi Wustha Al-Amiriyyah Banyuwangi Education Unit produced an Islamic boarding school-based learning tool with a PBL model that is valid, practical, and effective and can provide an opportunity to improve the numeracy skills of students. Valid criteria are obtained based on three validators' validity tests to determine whether the learning device carries out the measuring function correctly. Practicality criteria were obtained from student activities of 90.7%, learning implementation of 3.56, which means high value, and student questionnaire responses, which showed positive value. Meanwhile, the effectiveness criteria from the learning outcomes data obtained 87.0% classical completion. Not only that but effectiveness can also be seen from the numerical ability to increase N-Gain, which shows an average of 0.73 in the high category.

The exciting thing about this research is that it is at the development stage. It can be seen from the data obtained by observers that at the first meeting, it was 3.25, while at the second meeting, it increased to 3.58, and at the third meeting, it increased to 3.83. There was always an increase at each meeting. It

shows that teachers were not used to using Islamic boarding school-based learning tools with the PBL model at the first meeting. Then, at the first meeting, there were some students who acted passively; there were no visible numeracy indicators and no initiative to ask questions; then, at the next meeting, the students slowly showed themselves to behave more actively, such as using concepts, facts, and reasons to complete the problem-solving process.

Based on observation data, this success is supported by teachers who intensively read user manuals that guide teachers' learning processes according to teaching modules using the PBL model. This data was obtained based on the results of interviews conducted with model teachers after the learning was completed. It is in line with Arifin 2020, Tesfaw *et al.*, 2024, that the instruction book is not only a direction but also a teacher's guide in making it easier to explain the material through the achievement of learning objectives.



Figure 4. Learning process

Student Worksheets (LKPD), which are developed in such a way that uses the PBL model and numeracy indicators, can improve students' numeracy skills. Based on Figure 2, the students are more enthusiastic and eager to learn and discuss with their groups to solve the problems in the LKPD that has been distributed. This can also be seen from the results of observations, from initially only 1-2 groups that were active and showing numeracy indicators to almost the entire group showing good numeracy indicators during the problem-solving process. This is in line with research conducted by Festina & Warniasih (2021) that Student Worksheets (LKPD) with the PBL model can facilitate mathematical problem-solving abilities, as well as the problem-solving process, encouraging students to learn mathematics themselves (Pambudi et al., 2020).

The scaffolding in the Student Worksheets (LKPD) aims to guide students independently in solving problems. This was confirmed by Yuliawanti et al. (2019), who stated that the scaffolding involved in PBL syntax can accommodate students' problem-solving abilities. Based on the results of observations at meeting 3, the students were more enthusiastic, and learning was progressing conducive; the students worked together to solve problems, and the entire group solved problems independently by utilizing the scaffolding on the Student Worksheets (LKPD). During the presentation activity, each group representative asked questions for the presenting group, and the entire group concluded the results of the learning that had been carried out. In line with this, the use of learning tools in the context of everyday life helps students learn abstract mathematical concepts through representation, thereby increasing students' motivation to study mathematics (Putri & Zulkardi, 2020).

① ⇒ Diketahui :

$$\begin{aligned} \text{Zakat} &= 2,5\% \\ \text{Shodaqoh} &= 5\% \end{aligned}$$

⇒ Jawab :

$$\begin{aligned} \text{Zakat} &= \frac{2,5}{100} \times 4.000.000 = 100.000 \\ \text{Shodaqoh} &= \frac{5}{100} \times 4.000.000 = 200.000 \end{aligned}$$

| | |
|------------------|--|
| Translate: Given | |
| Zakat | : 2,5% |
| Shodaqoh | : 5% |
| Answer : | |
| Zakat | : $2,5/100 \times 4.000.000 = 100.000$ |
| Shodaqoh | : $5/100 \times 4.000.000 = 200.000$ |

Diketahui :

Zakat = 2,5% dari gaji
 Shodaqoh = 5% dari gaji di kurang zakat
 Gaji = 4.000.000

Di tanya :

Berapakah uang yang di shodaqahkan Ust. Umar untuk pembangunan masjid?

Jawab :

Konsep → pajak, zakat, proyeksi

$$\begin{aligned} \text{Zakat} &= \frac{2,5}{100} \times 4.000.000 = 100.000 \\ \text{Shodaqoh} &= (\text{Gaji} - \text{Zakat}) \times 5\% \\ &= (4.000.000 - 100.000) \times \frac{5}{100} \\ &= 3.900.000 \times \frac{5}{100} \\ &= 195.000 \end{aligned}$$

Jadi uang yang di shodaqahkan Ust. Umar untuk pembangunan masjid adalah 195.000

| | |
|--|---|
| Given: | |
| Zakat | = 2.5% of salary |
| Shodaqoh | = 5% of salary minus zakat |
| Salary | = 4,000,000 |
| Asked: | |
| how much money did Ust give shodaqoh? Umar for the construction of the mosque? | |
| Answer : | |
| Zakat | = $2,5/100 \times 4,000,000 = 100,000$ |
| Shodaqoh | = $(\text{salary} - \text{zakat}) \times 5\%$ |
| | = $(4,000,000 - 100,000) \times 5/100$ |
| | = $3,900,000 \times 5/100$ |
| | = 195,000 |
| So the money donated by Ust. Umar for the construction of the mosque was 195,000 | |

Figure 5. Pre-test and post-test results of students' numeracy abilities

Then, after the learning using Islamic boarding school-based learning tools is completed, a test is held to determine whether there has been an improvement in the students' numeracy skills. Based on Figure 5. It can be seen from the pre-test (upside) results that the students have been able to simplify known problems. However, they have not yet been able to design a problem-solving strategy, so the answers are still incorrect, and they have not been able to conclude and interpret the results of the answers in the students' sense. Meanwhile, in the post-test results (downside), the students have

produced the three numeracy indicators, namely, being able to simplify problems by using mathematical concepts correctly. They have been able to design a solution strategy correctly and have been able to interpret and conclude the results of the answers reasonably.

Based on Figure 5. The numeracy skills of students can be increased by applying problems that are appropriate to the context of everyday life, which in this case is the problem of zakat, which is very closely related to the daily life of Islamic boarding schools. This is in line with research conducted by (Wahyuningtyas *et al.*, 2020), which states that the contextual approach effectively supports students' numeracy abilities.

From the description presented, this research produces Islamic boarding school-based learning tools with a PBL model that is valid, practical, and effective and can improve students' numeracy skills. These good numeracy skills impact students in terms of helping them understand the application of mathematics in everyday life. Apart from that, students can use numeracy skills to project and interpret data and solve everyday problems (Masfufah & Afriansyah, 2021). In this way, we can develop qualified individuals to manage natural resources so that we can compete with other nations (Masjaya & Wardono, 2018).

Implications of Research

Further research is expected to use the findings of this research as reference material to apply more varied and innovative teaching and learning activities. Other researchers should conduct additional research to develop learning tools that use various materials and numeracy skills by a broader research subject.

Limitations

This research has limitations, namely that at the dissemination stage, it was carried out on a limited basis, and it was only distributed at the Muadalah Wustha school in Banyuwangi and several other sites. *Online* just. In addition, the research was conducted only at one school and for a limited time. In addition, it is hoped that dissemination activities will not only aim to be widely disseminated but that later, the tools developed can be used by other teachers and tested, thus allowing for criticism and suggestions for continuous improvement based on input from other people regarding the tools.

CONCLUSION

In the discussions that have been carried out, the PBL model Islamic boarding school-based mathematics learning tools developed using the 4D model can improve the numeracy skills of students. Findings obtained during the learning process were that there were no learning tools that could improve the numeracy skills of students, so the existence of Islamic boarding school-based mathematics learning tools with the PBL model provided an alternative for teachers and students to familiarize themselves with numeracy skills and improve numeracy skills as evidenced by the average gains. The average N-Gain value is in the high category. So, the development of Islamic boarding school-based learning tools using the Problem-Based Learning model has fulfilled the valid, practical, and effective categories.

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Analysis of Students' Mathematical Concept Understanding Ability in Terms of Student Resilience at Ban Kadeng School Thailand

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Abstract

Concept understanding ability is one of the main elements in learning mathematics. Understanding students' concept understanding ability will help teachers to plan better learning. Therefore, by understanding students' concepts, understanding ability, and resilience, teachers can improve the quality of education in a school. This study aims to analyze the relationship between students' resilience and understanding of mathematical concepts through story problems. The type of research is qualitative descriptive, the subject of this research is fifth-grade students of Ban Kadeng School, Thailand, and the object of research is the ability to understand students' mathematics concepts in terms of student resilience. The research instruments used are the resilience questionnaire, concept understanding ability test questions, and interviews. The analysis was carried out on indicators of concept understanding, such as restating concepts, classifying objects based on mathematical concepts, and giving examples or counterexamples to the concepts being learned obtained through the instruments that have been carried out. The results showed that in the ability to understand mathematical concepts, Ban Kadeng School students have a moderate level of resilience, namely 65% of students can understand the two main indicators, 25% of students with high resilience can understand all indicators, and 10% of students with low resilience are lacking in understanding the given indicators. So it can be concluded that there are differences in concept understanding ability between high resilience, moderate resilience, and low resilience students in class V Ban Kadeng School, Thailand. The results of this study can be used as a basis for research on the application of learning models, assessments, or types of feedback that are appropriate for students.

Keywords: Understanding; Mathematical Concepts; Resilience

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Subject classification 97C30 Cognitive processes, learning theories (aspects of mathematics education)

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Abstrak

Kemampuan pemahaaman konsep adalah salah satu unsur utama dalam belajar matematika. Memahami kemampuan pemahaman konsep siswa, akan membantu guru dalam merencanakan pembelajaran yang lebih baik. Oleh sebab itu, dengan memahami kemampuan pemahaman konsep, serta resiliensi siswa, guru akan mampu memperbaiki kualitas pendidikan di suatu sekolah. Penelitian ini bertujuan untuk menganalisis antara resiliensi siswa dan pemahaman konsep matematis melalui penggunaan soal cerita. Jenis penelitian deskriptif kualitatif, subjek penelitian ini adalah siswa kelas V BanKadeng School, Thailand, dan objek penelitiannya adalah kemampuan pemahaman konsep Matematika siswa ditinjau dari resiliensi siswa. Instrumen penelitian yang digunakan adalah angket resiliensi, soal tes kemampuan pemahaman konsep dan wawancara. Analisis dilakukan terhadap indikator pemahaman konsep, seperti menyatakan ulang konsep, mengklasifikasikan objek berdasarkan konsep matematika, dan memberikan contoh atau kontra contoh pada konsep yang dipelajari yang diperoleh melalui instrumen yang telah dilakukan. Hasil penelitian menunjukkan dalam kemampuan pemahaman konsep matematis siswa Ban Kadeng School memiliki tingkat resiliensi sedang yaitu sebanyak 65% siswa dapat memahami dua indikator utama, siswa dengan resiliensi tinggi sebanyak 25% dapat memahami keseluruhan indikator, dan siswa dengan resiliensi rendah sebanyak 10% kurang dalam memahami indikator yang diberikan. Jadi dapat disimpulkan bahwa terdapat perbedaan kemampuan pemahaman konsep antara siswa resiliensi tinggi, resiliensi sedang, dan resiliensi rendah di kelas V Ban Kadeng School, Thailand. Hasil penelitian ini dapat digunakan sebagai dasar untuk riset tentang penerapan model pembelajaran, asesmen, ataupun jenis feedback yang tepat untuk siswa.

INTRODUCTION

Concept understanding is the basis for learning mathematics (Wulansari et al., 2021). Conceptual ability must be acquired by a student (Kementrian Pendidikan dan Kebudayaan Republik Indonesia 2016) stated that concept understanding is the basis for learning mathematics (Afifah et al., 2024). In previous research, it was also stated that in a learning process, the ability to understand concepts is fundamental. (Syaifar et al., 2022). Understanding concepts in mathematics is related to each other, so it will be difficult for students to learn the next material if they are constrained in understanding the concepts (Fairus et al., 2023). Dahar mentions that "if compared to concepts, concepts are the building blocks of thinking", therefore students who are unable to understand concepts well will find it difficult to continue to the next learning (Aledya, 2019). Concept understanding is the ability of students to master the material and students can reapply the material with a more understandable language, not only knowing or remembering the concepts learned. (Suendarti &

Liberna, 2021). The ability of students to understand mathematical ideas in an applied and universal manner can be called concept understanding. The ability to understand concepts is very important for students to be able to continue learning at the next level. However, the low ability of students to understand mathematical concepts is a problem. This can be seen from the results of the Trends in International Mathematics and Sciences study (TIMSS) survey, where Indonesia is ranked 6th from the bottom (Natasya et al., 2023).

Conceptual understanding refers to an integrated and functional understanding of mathematical ideas. Students with conceptual understanding know more than just isolated facts and methods. They understand why the mathematical idea is important and the type of context in which the idea is useful. They have organized their knowledge into a coherent whole, which allows them to learn new ideas by connecting those ideas to what they already know. Conceptual understanding also supports retention because facts and methods learned with understanding are connected, so they are easier to remember and use, and indeed

reconstructed when forgotten (Bartell et al., 2013; Booth, 2002; Godino, 1996; Schoenbach et al., 1999; Yuliani & Suragih, 2015)

Furthermore, to understand a concept Polya said the importance of understanding the problem. A problem is a big problem, if it is very difficult then it is only a small problem if it is only slightly difficult. But a certain degree of difficulty is part of the idea of a problem, if there is no difficulty then there is no problem. A common problem is finding your way to a predetermined place in unfamiliar territory. We can easily imagine how serious this problem must have been for our primitive ancestors living in the primeval forest. This may or may not be the reason why the solution to a problem looks like finding a way: a way out of difficulty, a way out of obstacles (Polya, 1962).

To understand a concept, one must understand the problem too. The purpose of the "problem to find" is to find a particular object, the unknown of a problem, fulfilling the condition of the problem that connects the unknown with the data of the problem. Let us consider two examples. Given two line segments a and b , and angle y , construct a parallelogram whose line segments are adjacent sides including angle y . Given two line segments a and b , and angle y , construct a parallelogram whose line segments are its diagonals including angle y . In both problems, the data is the same, line segments a and b , and angle y . In both problems, the unknown is a parallelogram so our problems cannot be distinguished a priori based on the properties of the unknown. What distinguishes our two problems is the condition, the necessary relation between the unknown and the data: of course, the relation of the parallelogram to its sides is different from its relation to its diagonals (Aslan, 2021; Burton, 1984; Gravemeijer &

Doorman, 1999; Herbst, 2006; Leavy & Hourigan, 2020)

In terms of understanding concepts, everyone has differences in dealing with the problems they have (Wahyuti et al., 2023). In dealing with difficult situations, students are expected to have resilient behavior, namely if a person can deal with the problems being faced positively and can survive until they get the expected results (Ramadanti & Herdi, 2022). In learning mathematics, to understand the concept, resilience is important. Click or tap here to enter text. Resilience has an important role in mathematics learning because students tend to be able to confidently deal with the difficulties, they face (Maarif et al., 2023). Resilience can also be interpreted as a student's positive behavior in dealing with problems and not giving up easily when experiencing difficulties (Rahmatiya & Miatun, 2020). This includes a positive attitude and perseverance, which have a significant impact on success in tackling maths problems (Nyagani & Kristinawati, 2021). However, the low ability of students to understand mathematical concepts is a problem, what must be done is to instill mathematical resilience in students (Al Ghifari et al., 2022). Resilience is needed in mathematics because it can help review students in learning, things that make students tend to feel heavy and dislike learning mathematics (Awais et al., 2023; Setiawan et al., 2022). Mathematical resilience includes a strong desire to learn mathematics, self-confidence, and resilience in the face of adversity (Salsabila & Hadi, 2023). Academic resilience is also important because it allows students to get back on track after experiencing difficulties. (Mardhatillah et al., 2022). Resilience in students is necessary because it can stimulate student confidence and will get good results (Azizah & Abadi, 2022). The high

resilience of students will show an attitude that does not give up easily and always seeks a way out of the problems faced. (Ang *et al.*, 2022; Lee & Lee, 2023; Lutfiyana *et al.*, 2023). In line with that, previous researchers also stated that as much as 50.3% of understanding ability and learning tendencies were related to mathematical resilience, which means that resilience and learning tendencies greatly affect mathematical ability (Eliza *et al.*, 2023). According to the statement (Arifin, 2020; Mai *et al.*, 2021), mathematical resilience is the ability to respond to the difficulty of solving mathematical concept problems.

In observations made by researchers in collaborative research with teachers at partner schools, the learning model used at Ban Kadeng school, especially mathematics teachers, uses several learning models, one of which is the lecture method. In the lecture method, students listen to the learning material presented, after which students are given questions related to the material and answered together. The second is teaching using the help of learning media where in the learning process the teacher demonstrates learning media related to the material presented, the teacher also demonstrates learning media in the classroom, after which the teacher gives exercises to students. One of the media that teachers use in the learning process is class television, in the learning provided sometimes the teacher will give practice assignments to do at home outside the tasks that have been done at school.

In Ban Kadeng School's fifth-grade students, it was found that most of the students were not very interested in mathematics for various reasons, one of which is the doctrine embedded in their minds that mathematics is a scary subject. Previous researchers also (Ansori, 2020) stated that

some students feel anxious and consider maths difficult and boring. In this case, students' resilience is faced with challenges, especially in overcoming difficulties in understanding mathematical concepts. Cooperation between teachers, students, and educational institutions is needed to improve resilience. This is relevant to previous research; research shows there is a positive contribution to students who have good mathematical resilience to mathematical learning. (rizqa *et al.*, 2020).

Based on the things that have been described above regarding the ability to understand concepts and student resilience, a study was conducted with the title "Analysis of Students' Mathematical Concept Understanding Ability in Terms of Resilience at Ban Kadeng School" aims to understand the relationship between students' mathematical concept understanding ability and student resilience at the school. The benefits of the research include theoretical contributions to the understanding of mathematical concepts and practical benefits for students, teachers, schools, and researchers. Thus, this research is expected to make a significant contribution to the development of mathematics education at Ban Kadeng School and more broadly in the realm of national education in Thailand.

METHOD

In the introduction, it has been described how concept understanding is important to be studied. Therefore, to find out how the level of concept understanding and students' resilience in mathematics, it is necessary to conduct research that describes these phenomena. This research is a descriptive study with a qualitative approach at Ban Kadeng School, Narathiwat, Thailand, for fifth-grade students. The aims and

objectives of this study were to describe the ability to understand mathematical concepts in terms of student resilience in solving story problems on fraction material. Data collection in this study used a student resilience questionnaire, mathematical concept understanding story problems on fraction material, and interview guidelines.

Table 1. Resilience questionnaire grid

| No. | Indicators of student resilience | Questionnaire number |
|-----|--|-----------------------------|
| 1. | (a) Convinced that Mathematics is important and worthwhile | 1,10,20 |
| 2. | There is a strong sense of desire to learn Mathematics, even when facing unpleasant things and difficulties in the learning process; | 2,3,5,16,18,21 |
| 3. | Confidence in one's ability to learn and master mathematics, based on an understanding of mathematics, the ability to create strategies, the help of tools and other people, and the experience built; | 7,8,11,13,14,15,17,19,23,24 |
| 4. | There is a strong sense of going through the difficulties experienced, not giving up easily, and always giving a positive response in learning mathematics. | 4,6,9,12,22,25 |

The sample used in this study was class V students consisting of 20 people. Data collection methods involved a mathematical resilience questionnaire, mathematical concept understanding ability test, and interview. The mathematical resilience questionnaire includes 25 statements with a certain score, followed by a narrative-based mathematical concept understanding test given to students as many as 5 questions about fraction material and each question represents an indicator of students' mathematical concept understanding. Interviews were conducted to gain a deeper understanding of the relationship between student resilience and mathematical concept

understanding. The sampling technique in this study uses purposive sampling, namely the researcher takes samples by determining the characteristics that are by the research objectives so that they are the research objectives and can answer research problems (Imam, 2023). The above data collection techniques were validated by 2 experts (a Mathematics teacher at Ban Kadeng School, Thailand, and a lecturer in mathematics education at Universitas Muhammadiyah Tapanuli Selatan). The data will be analyzed through data reduction, by grouping students' resilience into high, moderate, and low. The results are expected to provide an overview of the correlation between student resilience and mathematical concept understanding ability at Ban Kadeng School. Students are categorized as having high resilience if $77 >$, Students are categorized as having moderate resilience if $66 \leq x < 77$, and Students are categorized as having low resilience if ≤ 66 . This instrument is carried out offline after that, the recapitulated results are selected from 3 students from each level of high, moderate, and low resilience. After that the researcher will analyze students based on the level of resilience to the students' mathematical concept understanding ability by utilizing instruments in the form of mathematical concept understanding ability test questions which are arranged based on indicators of mathematical concept understanding, the researcher also conducts interviews based on the results of students' mathematical concept understanding tests on fraction material interviews conducted in this study are arranged based on indicators of mathematical concept understanding. Data were obtained through triangulation techniques, comparing the results of observations, questionnaires, and interviews with mathematics teachers at Ban

Kadeng School. All data obtained, both from observations of student activities and interviews, were analyzed using the data reduction method to obtain systematic information and can be interpreted clearly.

The research stages are presented in the flowchart as follows:

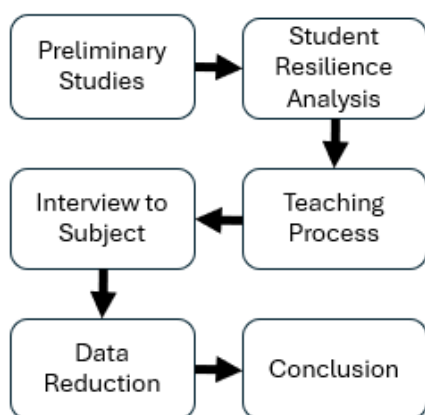


Figure 1. Research Stages

RESULT AND DISCUSSION

Result

The researcher analyzed the students' mathematical concept understanding ability in terms of student resilience according to the indicators of mathematical concept understanding ability, which was obtained through the answers to the mathematical concept understanding ability test questions and, conducted interviews to find out more about the concept understanding ability possessed by students. So then an analysis is carried out to get an idea of how much the ability to understand students' concepts in terms of student resilience.

Table 2. Percentage of student resilience

| Score (x) | Resilience level | Number of students | Percentage |
|------------------|------------------|--------------------|------------|
| $x \leq 66$ | Low | 2 | 10% |
| $66 \leq x < 77$ | Moderate | 13 | 65% |
| $x \geq 77$ | High | 5 | 25% |

Based on Table 2, the resilience of fifth-grade students at Ban Kadeng School is at a moderate level, namely 65% as many as 13 people, while high resilience is at a percentage of 25% and low resilience is a percentage of 10%. To determine the concept understanding ability of students, researchers conducted tests on story problems that were the indicators of understanding mathematical concepts.

Table 3. Indicators of concept understanding ability

| Indicator of Concept Understanding Ability | Sub Indicators | No. Question |
|---|---|--------------|
| Restate a concept. | Explaining concepts related to fractions | 1 |
| Classify objects based on mathematical concepts. | a) determine the parts or properties found in addition fractions | 2 |
| | b) determine the parts or properties found in multiplication fractions | 3 |
| Provide examples or counter-examples on the concept learned | a) Giving opinion in distinguishing which is the solution in fraction operation | 4 |
| | b) Giving opinion in distinguishing which way of working in fractions | 5 |

From the questions that have been done by students by the indicators of concept understanding, researchers take samples of student answers from each different level of resilience, namely high, moderate, and low resilience levels. To find out the differences in concept understanding abilities possessed by the three students with different resilience.

Table 4. Analysed student data

| Category | Student ID | PR | NS |
|----------|------------|-----|-----|
| High | RT | 83% | 100 |
| Moderate | RS | 72% | 80 |
| Low | RR | 62% | 40 |

Description: NR: Narrative Problem Score, PR: Resilience Percentage

Mathematical concept understanding ability in high resilience students

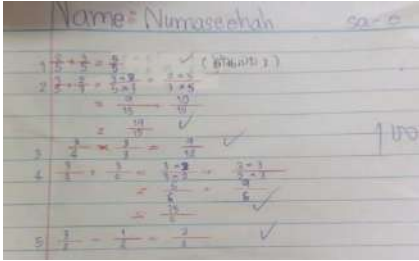


Figure 1. High resilience students' answers.

Students can solve problems and understand the understanding of concepts based on indicators of restating a concept, namely, students can follow the understanding of mathematical concepts, and can answer the type of fraction that has been solved. This can be seen in Figure 1 which has been attached. In problem 1, students can answer the types of fractions contained in the problem, this is by the indicators of students' understanding of mathematical concepts in fraction material restating a student concept. In question 2, students can describe the answer well and precisely. In question 3, students can work on problems with multiplication operations, which means that students can distinguish the work between multiplication and addition fraction operations by the indicators of understanding concepts and classifying objects based on mathematical concepts. In question 4, students are also able to describe the answer correctly based on students' understanding of working with fractions with addition operations. In question 5, in giving examples or counter-examples,

students were able to distinguish problem-solving between addition and subtraction in fractions. To obtain clearer data about the ability to understand mathematical concepts of students, researchers conducted interviews regarding indicators of understanding mathematical concepts.

In the interview results, students with high resilience can confidently provide a simple explanation of the questions that have been asked by the researcher. From the results of interviews and test questions, students with high resilience on indicators of understanding of student mathematical concepts on fraction material students can restate a concept, students can classify objects based on mathematical concepts students with high resilience can explain the properties of the fraction operations they have completed. Students also explain how the properties of fractions in multiplication or addition operations smoothly. On the indicator of students' understanding of mathematical concepts on fraction material Provide examples or counter-examples in the concepts studied. Students with high resilience can distinguish the workmanship in working on fraction problems. Able to provide a brief explanation of how to work on fractions with different operations. Students with high resilience do not have problems in understanding mathematical concepts in fraction material, high resilience students can easily solve the problems given smoothly and can write how to work on the problems given correctly. The results showed that students with high resilience were able to restate concepts, classify objects, and provide examples or counter-examples on fraction materials.

Mathematical concept understanding ability in moderate resilience level students



Figure 2. Answers of moderate resilience students

In the indicator of students' understanding of mathematical concepts on fraction material, restating a concept of students with moderate resilience (RS). Students with moderate resilience can provide a simple explanation of the questions that have been asked by researchers but have doubts about stating the types of fractions listed on the questions given. This can be seen in Figure 2 which has been attached. In question 1, students can answer the questions that have been given but, doubt in answering the type of fraction contained in the answer obtained. In question 2, students who have the right answer only attach the answer and cannot describe the answer properly and precisely in the test question. In question 3, students can work on problems with multiplication operations, which means students can distinguish the work between multiplication and addition fraction operations. In question 4, the student gave the wrong answer on the answer sheet, the student gave the right result for the numerator but the wrong answer for the denominator. In question 5, students were able to differentiate the problem-solving between addition and subtraction in fractions. To obtain clearer data about the ability to understand

mathematical concepts of students, researchers conducted interviews regarding indicators of understanding mathematical concepts, especially on students' clarity of the answers that have been attached. In the interview results, students with moderate resilience can answer some of the questions given but are lacking in providing a simple explanation of the questions that have been asked by the researcher.

The results of the analysis of test questions and interviews conducted on indicators of students' understanding of mathematical concepts on fraction material can classify objects based on mathematical concepts, and students with moderate resilience can explain the properties of the fraction operations they have completed. Students also explain how the properties of fractions in multiplication or addition operations smoothly. However, students with moderate resilience do not apply the solution to the answers written down. On the indicator of students' understanding of mathematical concepts on fraction material Provide examples or counter-examples in the concepts studied. Students with moderate resilience can distinguish workmanship in working on fraction problems. Able to provide a brief explanation of how to work on fractions with different operations. However, it is constrained to solving fraction problems with subtraction operations, because students feel that every fraction works on different operations has a different way.

Students with moderate resilience do not have problems at the worrying stage, it's just that students with moderate resilience need more emphasis and explanation in the learning provided. Moderate resilience students show ability in the first two indicators, but there is a tendency to lack confidence in providing explanations for

fraction operations. On the other hand, low-resilience students have difficulty in restating concepts, classifying objects, and providing examples or counter-examples on fraction materials.

Mathematical concept understanding ability of low resilience students

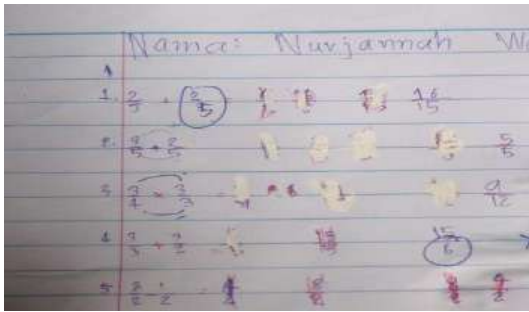


Figure 3. Low resilience students' answers

In the indicator of understanding mathematical concepts, students on fraction material restate a concept with low resilience (RR). Students with low resilience cannot explain the types of fractions in the problem. This can be seen in Figure 3 which has been attached. In question 1, students were unable to answer the questions that had been given, and there were a lot of scribbles on the student's answer sheet which meant that students were doubtful in the answers given. In question 2, students who have the right answer only attach the answer and cannot describe the answer properly and precisely in the test question. In question 3, students can work on problems with multiplication operations, which means that students can distinguish the work between multiplication and addition fraction operations. In question 4, the student gave the right answer after several times giving the wrong answer. In question 5, the student was not able to distinguish the problem-solving between addition and subtraction in fractions. To obtain clearer data about the ability to understand mathematical

concepts of students, researchers conducted interviews regarding indicators of understanding mathematical concepts, especially on students' clarity of the answers that have been attached. In the interview results, students with low resilience can answer some of the questions given but are lacking in providing a simple explanation of the questions that have been asked by the researcher. From the results of test questions and interviews conducted, the results obtained by low resilience students on indicators of understanding of student mathematical concepts in fraction material in restating a concept student are unable to explain or write down. classify objects based on mathematical concepts students with low resilience cannot explain the properties of the fraction operations they have completed and, in the questions, given students are also wrong in their work. Giving examples and counter-examples students are only able to provide a little explanation about the differences in working on problems with different operations. Students with low resilience have a problem that is quite worrying because these students have problems solving problems and can hardly understand the overall concept understanding ability. Students with moderate resilience also have low levels of confidence and doubt about what has been completed. Low resilience students have difficulty in restating concepts, classifying objects, and providing examples or counter-examples in fraction material.

Table 5. Students' comprehension ability based on students' resilience level

| Concept Understanding Indicator | Subject | | | Number of questions that can be answered | | |
|--|---------|----|----|--|------|----|
| | RT | RS | RR | RT | RR | RR |
| Restate a concept. | ✓ | ✓ | - | 1 | 1 | 1 |
| Classify objects based on mathematical concepts. | ✓ | - | - | 2, 3 | 2, 3 | 3 |
| Provide examples or counter-examples on the concept being learned. | ✓ | ✓ | - | 4, 5 | 4 | - |

Description: RT: High Resilience, RS: Moderate Resilience, RR: Low Resilience

The results showed differences in the understanding of mathematical concepts about fractions between three groups of students with high (RT), moderate (RS), and low (RR) resilience levels. Students with a high level of resilience (RT) were able to deal well with various problems about fractions, showing strong concept understanding and good verbal ability in explaining the working process. On the other hand, students with a moderate level of resilience (RS) showed good ability in solving problems, but there was a tendency to lack confidence in mentioning types of fractions and providing detailed explanations.

Meanwhile, students with a low level of resilience (RR) showed the ability to solve problems, but difficulty in understanding fraction concepts and communicating understanding verbally. In conclusion, resilience can affect not only academic ability but also verbal ability and students' confidence in handling mathematical materials, such as understanding fraction concepts.

In understanding the concept of fraction material, high and moderate resilience students can understand the properties of the concept well, but moderate resilience students show doubts at certain points.

Low resilience students, on the other hand, experienced difficulties and inability in understanding the concept of fractions, especially in the aspects of restating concepts and giving examples or counter-examples.

Discussion

Several things become obstacles to improving concept understanding ability which are the findings of this research, namely:

Teachers often use the same standardized examples repeatedly. This can build greeting knowledge on that one concept. For example, isosceles triangles are rarely drawn with orientations other than having a horizontal base. This can lead students to conclude that the shape is not an isosceles triangle when rotated. This is not in line with the concepts of problems, problem-solving, and understanding. In various research, standardized examples need to be given to students as a learning experience. (Fried, 2006; Gravemeijer & Doorman, 1999; Nurhayati, 2013; Polya, 1962; Watson & Mason, 2005).

Simple but important things are not covered enough in learning; some important steps in understanding a topic may even be missed. For example, a good understanding of numbers, side, corner points, profit, loss, even collecting the data. Teachers often just hand out definitions without giving meaning. This is certainly in line with the results of previous research that in teaching teachers must be able to give meaning to the material presented. Teachers can build experiences based on the local environment, geography, and culture (Karlström & Hamza, 2019; Mitrevski & Zajkov, 2011; Pantić & Wubbels, 2010; Sahin-Taskin, 2017; Simons et al., 2020; Thiagarajan, 1974).

Students are not encouraged to make

connections between the different things they learn. For example, the meaning of a side, angle, in a cube, cuboid or cone. These concepts are connected but students often memorise these two things separately (Awais et al., 2023; Lee & Lee, 2023).

Lack of opportunities to visualize and observe phenomena, either through hands-on experiments or virtual simulations. For example, the concepts of volume and area. Students are often given in the form of formulas and calculations when given problems. They do not see that there is meaning in the words volume and area, which is a quantity. This is contrary to several studies that convey the need to give students experience. One of the important steps in the knowledge formation process is to provide real experiences to students. (Cesaria & Herman, 2019; Prabowo et al., 2021).

Teachers' (often unconscious) belief that students' minds are blank slates. When teachers teach without recognizing students' initial mental models, students may continue to maintain their unscientific beliefs while giving 'correct answers' in exams. Going back to the example of falling objects, a student may maintain his or her belief that 'heavier objects fall faster' even though the equations of motion learned in school contradict that belief. Students often do not realize that they hold these conflicting beliefs. Students' prior knowledge becomes a prerequisite in learning certain material. Students are considered to have good learning readiness if they have good pre-requisite skills. (Brousseau, 2002a, 2002b).

Implication of Research

The results of this study can be directly applied to the improvement of lesson plans for schoolteachers. In addition, this research

can also be the basis for other larger studies, namely the application of learning models, assessment models, or the application of feedback in learning so that students become more understanding of learning materials. Students also become more resilient in dealing with mathematical problems.

Limitation

The subjects of this study were grade 5 students at Ban Kadeng School. Students with characteristics such as the southern region of Thailand, with most Malay students, can apply the results of this research in their respective regions. However, this research cannot be generalized to different student characteristics. Further research needs to be conducted for more generalized results.

CONCLUSION

Based on the research findings, it is concluded that the ability to understand mathematical concepts of grade V students of Ban Kadeng School, Narathiwat, Thailand, in dealing with narrative problems can be reflected in the level of student resilience. In general, the resilience of fifth-grade students of Ban Kadeng School is included in the moderate category, which is 65%, the low category is 10%, and the high category is 25%. Students with high resilience can understand the whole concept, students with moderate resilience are only able to understand two main indicators of concept understanding, and moderate resilience students are hesitant in understanding all indicators of concept understanding. From the data above, student resilience affects the ability to understand mathematical concepts of students at Ban Kadeng School.

As a suggestion for teachers and students, they are expected to collaborate in

building resilience in students such as instilling motivation in students who have low resilience and for students to also be encouraged to be active in learning, practice working on narrative problems, and not hesitate to ask questions to others. Furthermore, to ensure this research is more accurate, it is hoped that future research will use a large enough data source and be carried out over a longer period than previous researchers.

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Analogical Reasoning of Sensing and Intuition Personality Student in Solving Proportion Problem: Two-Variable into Three-Variable Direct Proportion Word Problem

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Abstract

Students' analogical reasoning based on sensing and intuition is a topic that has yet to be studied. Specifically, there is a need to explore how these two personalities types process information and apply analogical reasoning to solve proportional problems. The research aims to describe the reasoning process based on students' personalities, especially as a first step in implementing more effective and tailored teaching. The type of research used is descriptive qualitative. The research involved four students, two with sensing personalities and two with intuition personalities, who were selected from a group of 32 seventh grade (A) students at SMP Negeri 3 Ambulu, Jember, Indonesia. Selecting four students allows the researcher to explore how students with sensing and intuition personalities use analogical reasoning. The selected subjects embody both personality types, guaranteeing the consistency and generalizability of the obtained data in a wider context. The triangulation used is a triangulation technique that compares the results of completing analogical reasoning tests and interviews. The results of this study show that students with sensing and intuition personalities show differences in analogical reasoning on proportion material. Sensing students carry out two stages of analogical reasoning, namely encoding and inferring; they identify all the information in the source and target problems, solve the source problem, and recognize material similarities and the context of snack production. However, they needed help at the mapping and applying stages; focusing on concrete details prevented them from seeing abstract relationships, and thus, they failed to use the concept of solving the source problem to the target problem. Meanwhile, intuition students carry out the four stages of analogical reasoning: encoding, inferring, mapping, and applying. They successfully identified information, concluded the source problem, a problem involving two elements, identified the relationship with the target problem, connected the solution steps from the source problem to the target problem, and applied the proportion concept to a more complex target problem. This research shows that students' analogical reasoning in proportion materials varies depending on their personality type. Therefore, we can potentially use the results of this research as a reference to implement differentiated learning.

Keywords: Analogical Reasoning, Sensing and Intuition, Proportion.

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Abstrak

Penalaran analogi siswa berdasarkan kepribadian sensing dan intuition merupakan topik yang belum banyak dikaji secara mendalam. Terutama, bagaimana kedua tipe kepribadian ini memproses informasi dan menerapkan penalaran analogi dalam menyelesaikan masalah perbandingan masih menjadi hal yang kurang dieksplorasi. Penelitian bertujuan untuk mendeskripsikan proses penalaran berdasarkan kepribadian siswa khususnya pada sebagai langkah awal dalam melaksanakan pengajaran yang lebih efektif dan disesuaikan. Jenis penelitian yang digunakan adalah deskriptif kualitatif. Banyak subjek dalam penelitian ini adalah 4 siswa dengan rincian 2 siswa kepribadian sensing dan 2 siswa kepribadian intuition yang dipilih dari 32 siswa kelas VIIA SMP Negeri 3 Ambulu Jember, Indonesia. Memilih empat siswa memungkinkan peneliti untuk mengeksplorasi secara mendalam bagaimana siswa dengan kepribadian sensing dan intuition menggunakan penalaran analogi. Subjek yang dipilih mewakili kedua tipe kepribadian, sehingga data yang diperoleh konsisten dan dapat digeneralisasi dalam konteks yang lebih luas. Triangulasi yang digunakan adalah triangulasi teknik yang membandingkan hasil penyelesaian tes penalaran analogi dan wawancara. Hasil penelitian ini menunjukkan bahwa siswa dengan kepribadian sensing dan intuition menunjukkan perbedaan dalam penalaran analogi pada materi perbandingan. Siswa sensing melakukan dua tahap penalaran analogi yaitu encoding dan inferring, mereka mengidentifikasi semua informasi dalam masalah sumber dan target serta menyelesaikan masalah sumber dan mengenali persamaan materi serta konteks produksi snack. Namun, mereka kesulitan pada tahap mapping dan applying, fokus pada detail konkret membuat mereka tidak melihat hubungan abstrak sehingga gagal menerapkan konsep penyelesaian masalah sumber ke masalah target. Sementara, siswa intuition melakukan keempat tahapan penalaran analogi: encoding, inferring, mapping, dan applying. Mereka berhasil mengidentifikasi informasi, menyimpulkan masalah sumber yang merupakan masalah perbandingan dua unsur dan mengidentifikasi keterkaitan dengan masalah target, menghubungkan langkah-langkah penyelesaian dari masalah sumber ke target, dan menerapkan konsep perbandingan ke masalah target yang lebih kompleks. Secara keseluruhan, penelitian ini menunjukkan bahwa penalaran analogi siswa dalam materi perbandingan bervariasi tergantung pada tipe kepribadian mereka. Oleh karena itu, hasil penelitian ini berpotensi untuk digunakan sebagai referensi dalam menerapkan pembelajaran berdiferensiasi yang mengakomodasi keberagaman tipe kepribadian.

INTRODUCTION

Mathematics plays an important role in life and understanding other sciences. This understanding of mathematics can be achieved through quality mathematics learning. There are five process standards in good mathematics learning, including problem-solving, reasoning and proof, connections, communication, and mathematical representation (NCTM, 2000).

Based on these standards, reasoning must be present in mathematics learning. Reasoning is thoughts adopted to produce statements and conclusions in solving problems (Lithner, 2008; Supratman, 2023). There are many types of reasoning that a person can do, one of which is analogical reasoning. This analogical reasoning is known for drawing conclusions based on similar processes or rules (Evans, 2019; Sumarmo, 2011).

Analogical reasoning is a person's way of making decisions about something new in their experience by comparing it

with something they already know. Sternberg (1977a) asserts that the application of analogical reasoning in mathematics learning presents students with a new problem (target), which they can solve using the same pattern, structure, and concept as a simple, previously studied old problem (source). Analogical reasoning involves finding a similar problem (source) to the target problem and mapping the solution from the source problem to the target problem (Lee, 1992).

Analogical reasoning in problem-solving involves transferring the explanation or solution procedure from the initial problem (source) to a new problem (target) (Tsoukas, 1991). English (2004) states that students need to adapt or expand the source problem procedure to be able to use it as a target problem-solving procedure. The source problem is easy and moderate, while the target problem is complex (Angraini et al., 2023; Gentner, 1983).

This analogical reasoning process

has several stages. Sternberg states four stages must be present in the analogical reasoning process: encoding, inferring, mapping, and applying (Sternberg, 1977b). This stage can be used to analyze the extent to which students carry out analogical reasoning in solving mathematical problems (Eskridge, 1989; Krstayulta et al., 2020).

This analogical reasoning can be used to understand mathematics and vice versa; mathematics can also be used to practice analogical reasoning (Sakinah & Hakim, 2023; Stevenson et al., 2013). A person cannot be separated from the use of his reasoning power (Wulandari et al., 2021). This means that analogical reasoning here is not only used in solving mathematical problems but can be used in many other things outside of mathematics (Gentner & Maravilla, 2018). This positive reciprocal relationship is vital to implementing mathematics learning based on analogical reasoning.

The explanation above indirectly states that this analogical reasoning involves collecting and processing information, such as the information in the source and target problem. At SMP Negeri 3 Ambulu Jember Indonesia, observations indicate that students have different approaches to solving math problems. Some students tend to focus on concrete details and specific steps in problem-solving, preferring systematic methods and often following clear procedures. This condition suggests there are varying tendencies in information processing. Based on these characteristics, the researcher identifies that these differences may be related to the sensing-intuition personality types. A person's way of taking in and processing information can be different due to differences in a person's characteristics. In the Myers-Briggs Type Indicator (MBTI), a person's differences in

taking in, perceiving, and processing information are put into one contrasting personality preference of sensing and intuition (Francis et al., 2020; Makwana, 2023; Myers et al., 1998). Sensing focuses on the reality of a situation as perceived by the senses, while intuition focuses on possibilities, meanings, and relationships (Francis et al., 2020).

Identifying students' analogical reasoning processes based on sensing and intuition personality needs to be done to realize differentiated mathematics learning. Differentiated learning accommodates, serves, and recognizes student diversity in learning according to students' readiness, interests, and preferences (Wulandari, 2022). Knowing the analogical reasoning tendencies of each personality type can be used as a reference in developing learning strategies, especially mathematics learning based on analogical reasoning.

Learning based on analogical reasoning can be applied to all material. Analogical reasoning is a highly effective tool in mathematical thinking (Hardiani & Kristayulita, 2023). One material that can be used is proportion. Proportion or ratio is a mathematical expression that compares two or more numbers (Lamon, 2020). This proportion is material that is often encountered and used in everyday life. The contextualization of this material will train students not only to reason in class but also in real situations. Regarding the research location, it has been outlined that there are differences in information processing methods, including in the material of proportion. Therefore, the researcher aims to further explore how students with sensing and intuition personalities use analogical reasoning and to identify the differences in their approaches to this material.

This research is also motivated by the lack of studies focusing on analogical

reasoning examined through the lens of sensing and intuition personality types, specifically concerning the material of proportion. Putri & Masriyah (2022) stated that students had similar analogical reasoning abilities with auditory and visual learning styles, while kinesthetic learning styles had lower analogical reasoning abilities than the other two learning styles in mathematics learning. Wulandari *et al.* (2021) state that students' analogical reasoning abilities in the cube and block material are directly proportional to their learning motivation. Sakinah & Hakim (2023) found diversity in students' analogical reasoning on curved-sided geometric shapes in the material. In conclusion, this study seeks to explore the differences in analogical reasoning between students with sensing and intuition personality types, particularly in solving proportion problems, and the results of this research can potentially be used as a reference in implementing differentiated learning.

METHOD

This research used a descriptive-qualitative approach. This approach is used in this study because it allows the researcher to deeply understand the analogical reasoning processes employed by students with sensing and intuition personalities. The research focuses on how students solve proportion problems with different variables, which is a complex context requiring detailed analysis. According to Creswell (2018), the qualitative approach is effective for exploring individual thought processes in real-world contexts, aligning with the objectives of this study. This research was conducted in class VII A of SMP Negeri 3 Ambulu Jember Indonesia in the 2023/2024 academic year with 34 students. The subjects are chosen us-

ing a purposive technique based on personality test results and daily test scores on proportion material with the equivalent high category. The results of the questionnaire filled out by 32 students showed that there were 25 students with sensing personalities and 7 students with intuition personalities. Next, 4 subjects were selected, consisting of 2 subjects with sensing personalities and 2 subjects with intuition personalities, based on their equally high scores in proportion material. Selecting four students allows the researcher to explore in-depth how students with sensing and intuition personalities use analogical reasoning to solve problems. With two students from each personality type, the researcher can observe and compare their thinking strategies and problem-solving approaches. The chosen subjects represent both personality types, ensuring that the data obtained is consistent and provides insights that can be generalized to a broader educational context. The reason for selecting subjects with similar high abilities is to ensure that the observed differences in analogical reasoning processes and learning outcomes are not influenced by variations in basic skill levels among students. By choosing subjects with comparable ability levels, the researcher can more accurately assess the impact of personality types on how students process and solve proportion problems. This allows for a clearer focus on the differences caused by personality types without additional variables related to differences in academic ability. The instruments used include a personality-type questionnaire adopted from Keirse (Keirse, 1998) and has been translated by Wibisono (Wibisono, 2023), analogical reasoning tests, and interview guides. The analogical reasoning test used in this research consists of one source problem and one target problem with direct proportion material. The

source problem uses two variables or items to be compared, while the target problem uses three variables or items, as in Table 1.

Table 1. Analogical Reasoning Test

| Source Problems | Target Problem |
|--|--|
| PT Citra Rasa is a company that produces snacks; in a day, the company can produce 250 kg of snacks using five units of production machines at the same speed. One day 2 units of production machines were damaged so the company could only use 3 units of its machines, which resulted in a decrease in the company's production output. How many snacks can the company produce that day? | PT Permadi Jaya is a company that produces snacks. The company can produce 200 kg of snacks in 6 hours using four machines with the same speed. One day, one of the production machines was damaged, so it could not be used. If the company's production time is 8 hours daily, how many snacks can be produced that day using the remaining machine? |

The data analysis technique follows the Miles, Huberman, and Saldana model, including data condensation, data presentation, and conclusion drawing (Miles et al., 2014). Triangulation techniques were used to ensure the data's validity by comparing test answer sheets and interview results. Data analysis is based on indicators adapted based on Sternberg's analogical reasoning stages (Sternberg, 1977b) developed by English (English, 2004) as in Table 2.

Table 2. Analogical Reasoning Process Indicators

| Stages | Indicators |
|-----------|---|
| Encoding | 1. Identify known information in the source problem and target problem 2. Mention the problem or question asked in the source problem and target problem |
| Inferring | 1. Determine concepts and solve source problems based on the concepts obtained |

| Stages | Indicators |
|----------|--|
| Mapping | 1. Linking source problems and target problems 2. Explain or describe the relationship between the concepts used in the source problem and the target problem. |
| Applying | 1. Determine the answer to the target problem 2. Determine the conclusion of the answer to the target problem by using the concept or method of solving the source problem. |

RESULTS AND DISCUSSION

Results

The subjects in this study consisted of 4 subjects. Sensing subjects are coded with S1 and S2, while intuition subjects 1 are coded N1 and intuition 2 are coded N1 and N2. The student answer sheet data in this study is presented as a copy written in the same way as the original.

Based on the data analysis results, this research's findings are written in Table 3.

Table 3. Research Findings

| Stages | Indicators | S1 | S2 | N2 | N1 |
|-----------|--|----|----|----|----|
| Encoding | Identify known information in the source problem and target problem | v | v | v | v |
| | Mention the problem or question asked in the source problem and target problem | v | v | v | v |
| Inferring | Determine concepts and solve source problems based on the concepts obtained | v | v | v | v |
| | Mention the relationship between the source problem and the target problem | v | v | v | v |
| Mapping | Linking source problems and target problems | | | v | v |

| Stages | Indicators | S1 | S2 | N2 | N1 |
|----------|--|----|----|----|----|
| | Explain or describe the relationship between the concepts used in the source problem and the target problem. | | v | v | |
| Applying | Determine the answer to the target problem | | v | v | |
| | Determine the conclusion of the answer to the target problem by using the concept or method of solving the source problem. | | v | v | |

We can see in Table 3 that the two sensing subjects carry out the same analogical reasoning as the intuition subject. The sensing subject fulfills the indicators of the encoding and inferring stages, while the intuition subject fulfills all the indicators of the analogical reasoning stages.

Analogical Reasoning of Students with Sensing Personalities

The results of the sensing subject's analogical reasoning test can be seen in Figure 1.

Next, the researcher will present the

results of the analysis of analogical reasoning and interviews with sensing students based on the four stages of analogical reasoning proposed by (Sternberg, 1977b).

Encoding

At this stage, sensing students still need clarification in writing down the information known in the source and target problems; however, sensing students have written it quite clearly in writing the required information. Figure 1 illustrates how sensing students record information from both the source and target problems, often using sentences that require revision or elicit multiple interpretations. Despite their lack of clarity in their writing, the sensing students were able to accurately explain the meaning of their answers during the interview session, as demonstrated in the following quote:

Q: What information do you think is given in terms of sources?

S: Known is that five machines can produce 250 kg of snacks.

1 Diket : 5 mesin 250 kg.
= Berapa banyak yang diproduksi oleh 3 mesin

Dijawab : Misal x sebagai banyak snack yang dihasilkan mesin

$$\text{masa} : \frac{250}{5} = \frac{x}{3}$$

$$5x = 750$$

$$x = \frac{750}{5}$$

$$= 150$$

Maka snack yang dihasilkan oleh 3 mesin itu adalah 150 kg

→ *inferring*

2 4 unit mesin 200 kg dalam 6 jam
Banyak snack yang dihasilkan oleh 3 mesin dalam 8 jam

Dijawab : misal 3 unit mesin x

$$= \frac{200}{4} \times \frac{x}{3}$$

$$= 600 = x4$$

$$x = \frac{600}{4} = 120$$

Jadi yang dihasilkan oleh 3 mesin adalah 120 kg

encoding

Translation:
Known : 5 machines 250 kg
: How much is produced by 3 machines

Answered :
let x be the number of snacks produced by the machine
then $\frac{250}{5} = \frac{x}{3}$
 $5x = 750$
 $x = \frac{750}{5}$
 $= 150$
then the snack produced by the 3 machines is 150 kg

4 units of 200 kg machine in 6 hours
Many snacks produced by 3 machines in 8 hours

Answered : for example, 3 units of machine is x
 $\frac{200}{4} = \frac{x}{3}$
 $600 = x4$
 $x = \frac{600}{4} = 120$
So the output of 3 machines is 120 kg

Figure 1. Analogical Sensing Reasoning Test Answer Sheet

Sensing students can fulfill the indicators at this stage or carry out the encoding stage.

Inferring

At this stage, sensing students succeeded in answering the source problem correctly. Sensing students use the concept of correct proportion calculations. Based on Figure 3, first, the sensing students expressed x as the number of snacks produced by the 3 machines. Next, sensing students create equal proportion equations and carry out calculations by cross-multiplying. From the results of the cross multiplication carried out by sensing students, they produced a linear equation with one variable $5x = 750$, so the value of x equals 150. Sensing students also explained the steps for solving it during the interview. During the interview, the sensing student also mentioned the connection between the source problem and the target problem, as in the following quote.

S: Both include direct proportion material, and there's also the same thing about snack production machines, sir.

Sensing students concluded that the connection between the two problems is in the material, which is a proportion of types of direct proportion, and the context of the problem, which is snack production. Therefore, sensing students can fulfill the indicators at this stage or carry out the inferring stage.

Mapping

Sensing students further explain the relationship between source and target problems at this stage. Sensing students stated that both problems asked about snack production results, but the target problem was more difficult because it involved production time. Based on Figure

4, sensing students using the initial steps uses the same concept as the source problem-solving steps. In making students' examples, sensing is still unclear. The sensing student's steps in making a proportion equation were correct, but sensing made a calculation error when determining the value of x , which was corrected during the interview. The sensing student's calculations stopped and concluded that the snacks produced by 3 machines were 120 kg. Sensing students need clarification when continuing calculations. This is confirmed based on interview results as in the following quote.

P: Try calculating again, how much is 600 divided by 4?

S: ehh yes sir, 150.

P: Do you can't continue?

S: Yes sir, I'm confused.

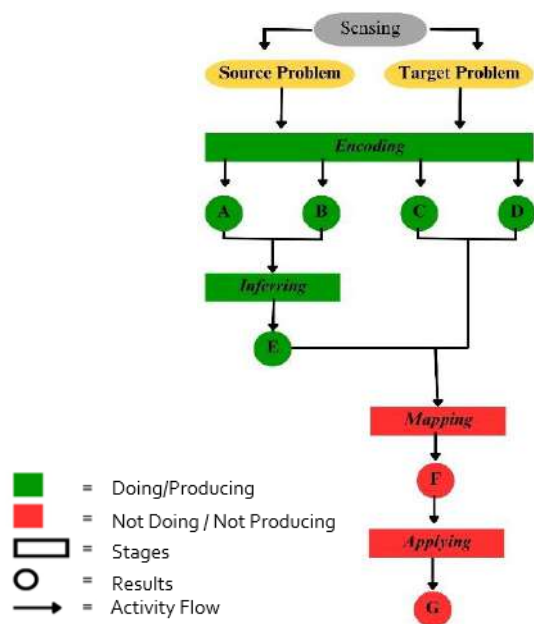
Based on the results of tests and interviews conducted show that sensing students cannot determine and connect source problems and target problems. Sensing students only try to solve the target problem using the same steps as the source problem, even though in the target problem, there are still further steps to determine the answer. Thus, sensing students didn't carry out the mapping stages.

Applying

In solving the problem, the target stops after concluding that the number of snacks produced by 3 machines is 150 kg without mentioning the production time. This conclusion is correct if the sensing student states that 150 kg is the number of snacks produced by 3 machines in 6 hours. Sensing student is unable to solve the given target problem. Therefore, sensing students can't carry out the applying stage.

The diagram in Figure 2 interprets the stages of analogical reasoning carried

out by sensing students.



- A = Information known in the source problem
 B = Information requested in the source problem
 C = Known information in the target problem
 D = Information requested in the target problem
 E = Answers and conclusions to source problems
 F = Relationship between solving source problems and target problems
 G = Answers and Conclusions to the target problem

Figure 2. Diagram of Sensing Students' Analogical Reasoning Stages

Analogical Reasoning of Students with Intuition Personality

The results of the sensing subject's analogical reasoning test can be seen in Figure 3.

Next, the researcher will present the results of the analysis of analogical reasoning and interviews with sensing students based on the four stages of analogical reasoning proposed by Sternberg (1977b).

Encoding

At this stage, intuition students identify the information known in the source and target problems well. Intuition students also mention the issues or things asked in

the two questions. Intuition Students' answers can be seen in Figure 3. Intuition students are still unclear in writing down the information they know. Intuition students wrote 5 machines = 250 kg for the known information in the source problem while in the target problem wrote 4 units of 200 kg machines in 6 hours. However, the student explained the meaning of his answer during the interview as in the following quote.

- S: five units of machines can produce 250 kg sir
 P: Good, then what are you known in the target problem?
 S: 4 units of machine produce 200 kg in 6 hours, sir

From this, we can conclude students can fulfill the indicators at this stage or carry out the encoding stage.

Inferring

Intuition students use the correct way to create equivalent proportion equations. Next, the intuition students performed proportion calculations using cross multiplication, producing a linear equation with one variable. Then, the intuition students found the value of the variable x that had been assumed previously. When writing the conclusion, the Intuition student did not write down the units for the number of snacks, but during the interview, the Intuition student stated that the answer to the source problem was 150 kg of snacks. Intuition students said both problems were equally related to snack production and comparable material. This was stated by intuition students in the following interview quote.

- S: The context of the question is both about snack production, and the material in the question is proportion material.

From here, it means determining the concept, solving the source problem, and clearly stating the relationship between

the two problems. Thus, intuition students fulfill the indicators at this stage or carry out the inferring stage.

Mapping

Based on Figure 3, intuition students do not involve time in their equations in the first step, so intuition students get an x value of 150, which is the number of snacks produced by 3 machines in 6 hours. This data shows that the concepts intuition uses in solving the target problem in the initial step use the same concepts as those used in solving the source problem; however, in the next step, intuition students do not use formal calculations to solve the problem. Intuition students also stated that the solution to the target problem was almost the same as in the following interview excerpt.

S: Almost the same, it can be done using the same concepts and proportion calculations, but the second one is more difficult

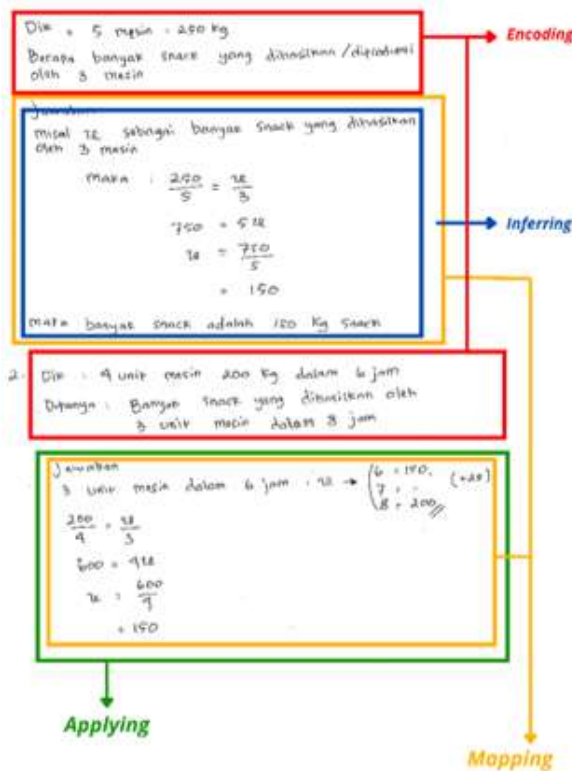
P: What are your steps to solve the target question?

S: First, let me assume that the number of snacks produced by 3 machines in 6 hours is x. Next, I looked for the value of x using the equivalent proportion equation, and the result was that I found the value $x = 150$. Next, I immediately assume that if 6 hours is 150, that means 1 hour is 150 divided by 6, the result is 25, if what is asked is 8 hours, then 25 multiplied by 8 results in 200.

From this, it is known that students' intuition connects the source problem and the target problem. Intuition students also describe the relationship between the concepts used in the source problem and the target problem. Thus, intuition students can fulfill the mapping stage indicators.

Applying

At this stage, students' intuition correctly determines the target problem's answer. As previously discussed, intuition students use two calculation steps to solve and derive conclusions from the target problem. In the first step, intuition stu-



Translation:
 Known : 5 machines 250 kg
 How many snacks are created or produced by 3 machines

Answered :
 let x be the number of snacks produced by 3 machines
 then $\frac{250}{5} = \frac{x}{3}$
 $750 = 5x$
 $x = \frac{750}{5}$
 $= 150$
 then the number of snacks is 150 kg of snacks

Known : 4 units of 200 kg machine in 6 hours
 Asked: The number of snacks produced by 3 machines in 8 hours.
 Answered :

3 units of machine in 6 hours = x $\rightarrow \left(\frac{6}{7} = 150, \begin{matrix} 7 = \dots (+25) \\ 8 = 200 \end{matrix} \right)$
 $\frac{200}{4} = \frac{x}{3}$
 $600 = 4x$
 $x = \frac{600}{4} = 150$

Figure 3. Intuition Student Answer Sheet

dents look for the number of snacks produced by 3 machines in 6 hours, as in Figure 3. In the next step, although intuition students do not use formal calculations to determine the number of snacks produced by 3 machines in 8 hours, intuition students use the concept unit calculation, which can also be considered a one-variable linear equation. Based on the interview results presented previously regarding the student's explanation of intuition about the steps to solving the target problem, the informal calculation can be interpreted as the following linear equation.

Intuition students concluded the answer to the target problem during the interview even though the results of their work on the answer sheet did not write their conclusions.

S: So the number of snacks produced by 3 machines takes 8 hours to produce 200kg.

Intuition students conclude that the number of snacks produced by 3 machines in 8 hours is 200 kg of snacks. Intuition students also stated that in the second calculation, they could also use the same calculation as the first calculation or the calculation used in the source question; only the proportion of the number of snacks with production time is used, which can be seen in the following interview quote.

P: OK, if you are looking for a continuation or looking for 8 hours, can you use the same method as the first step?

S: Yes, I think it's possible, sir

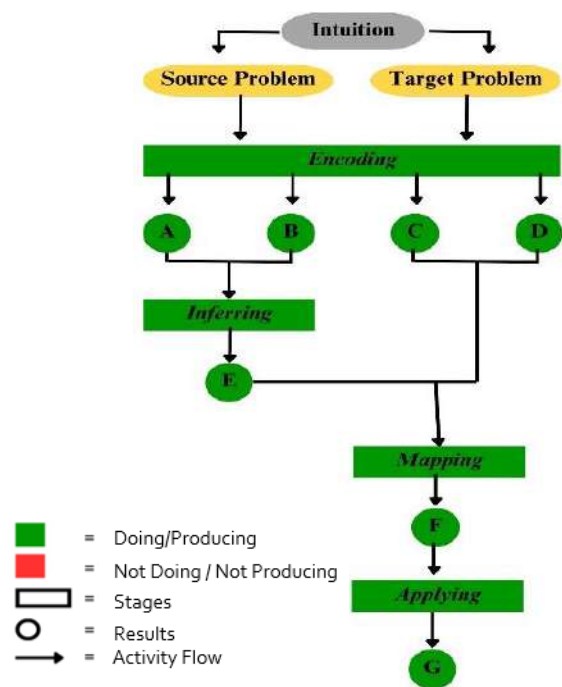
P: try to explain!

S: Yes, the first one is a proportion between the machine and snacks, the second one uses time and lots of snacks but uses the snacks calculated earlier, that's how it is, right??

Based on interviews, intuition students fulfill or carry out the stages of applying.

The diagram in Figure 4 interprets

the stages of analogical reasoning carried out by students with an intuition personality.



- = Doing/Producing
 - = Not Doing / Not Producing
 - = Stages
 - = Results
 - = Activity Flow
- A = Information known in the source problem*
B = Information requested in the source problem
C = Known information in the target problem
D = Information requested in the target problem
E = Answers and conclusions to source problems
F = Relationship between solving source problems and target problems
G = Answers and Conclusions to the target problem

Figure 4. Diagram of the Analogical Reasoning Stages of Intuition Students

Discussion

The research results show that the two personality types have different analogical reasoning. The diagrams in Figure 2 and Figure 4 show the stages of analogical reasoning for students of sensing and intuition.

Sensing students only carry out the encoding and inferring stages, they need to carry out the mapping and applying stages. Meanwhile, students of intuition engage in four stages of analogical reasoning. Personality type is one factor that influences students in solving problems, intelligence, and academics (Bardach et

al., 2023). According to Gahi et al. (2023), the problem-solving abilities of sensing and intuition students differ significantly. In line with (Kusumastuti et al., 2021b) intuition students achieve better results than sensing students. Students with an intuitive personality may excel in analogical reasoning due to their tendency to think creatively and identify patterns and relationships that are not immediately apparent. They tend to see the bigger picture and connect information in more complex ways, which can speed up solving proportion problems involving additional variables (Francis et al., 2020).

Analogical Reasoning of Students with Sensing Personality Types in Solving Direct Proportion Problems

Sensing students are responsible for completing the encoding stage. Sensing students are capable of accurately identifying known and requested information in both the source and target problems. Maharani (Maharani, 2020) also found in their research that sensing students can effectively convey the information present in the problem. Susilo (Susilo, 2019) also mentioned that students with sensing personalities carefully understand information.

Sensing students carry out the inferring stage. They define the concept, solve the source problem correctly, and state the connection between the source problem and the target problem. Sensing students observed that both the source and target problems were incorporated into the value proportion material and the context of the snack production problem. According to Nainggolan *et al* (Nainggolan et al., 2022), sensing students can determine the relevance of topics in solving given problems. Furthermore, he clarified that students of the sensing type process information based on what they have

learned (facts) and follow systematic steps. Sensing students can write and conclude answers to source problems coherently and clearly, in accordance with the characteristics of someone with a sensing personality. Sensing personalities tend to be able to provide information systematically (Tieger et al., 2017).

During the mapping stage, sensing students often struggle to establish a connection between the source problem and the target problem in terms of the solution. This is due to their tendency to concentrate on specific and concrete details, which prevents them from extending the concept from the source problem to the target problem. According to Nainggolan *et al* (Nainggolan et al., 2022), the sensing type only looks at the data as it is, so finding a connection has yet to be carried out optimally. This issue also arises due to the need to understand the abstract relationship between the two problems. Wijaya *et al* (Wijaya et al., 2019) stated that sensing students really don't like abstract things and prefer concrete things. This causes them to be more comfortable with direct information than theoretical concepts.

Students with sensing personalities also struggle to carry out the application stage. Sensing students did not use the concept of solving the source problem to work on the target problem, sensing students did not find the answer to the target problem. Sensing students only apply the same steps as the source problem, even though the target problem requires expanded steps to solve it here. Rohim and Sari (Rohim & Sari, 2019) assert that we can perceive sensing students as replicators, as they can only integrate and connect topics based on their prior knowledge. Kusumastuti (Kusumastuti et al., 2021a) also stated that sensing students prefer to repeat what they have read and studied. According to Myers (Myers et al., 1998) sensing focuses more

on what can happen and is felt by the five senses.

Analogical Reasoning of Students with the Intuition Personality Type in Solving Direct Proportional Problems

The results of this study show that intuition students carry out the encoding stage. Despite the unclear nature of the information on the answer sheet, the students can identify all the known and requested information. These results are in line with Nazarian and Authary (Nazariah & Authary, 2021). that students with intuition personality identify the information contained in the problem. Intuition students can define problems or can identify information that is known and stated in the problem, Tieger *et al* (Tieger *et al.*, 2017) state that someone with an intuition personality usually conveys information in leaps and bounds.

At the inferring stage, students' intuition correctly determines the concept, solves the source problem, and states the connection between the source problem and the target problem. Students still need to clarify several aspects of their intuition-based calculations in source problems. This is because it is based on one's intuition; according to Francis *et al.* (2020), intuition doesn't like to spend much time making the job more suitable. When it comes to identifying relationships, students' intuition aligns with what their senses convey. They stated that the source and target problem were included in the proportion material and the context of the problem regarding snack production. Identifying these relationships is easy for an intuitive because intuition processes data based on patterns and relationships (Nugroho *et al.*, 2020), intuition focuses primarily on perceiving patterns and interrelationships (Myers *et al.*, 1998).

Intuition students carry out the

mapping stages well. They link the steps of solving the source problem and the target problem. Students of intuition assert that they can solve the target problem using the same proportion calculations as the source problem, but they don't stop there; further calculations are still necessary to solve the target problem. A person's intuition is very reliable in identifying and building patterns and relationships from the information they receive. According to Nainggolon *et al.* (2022), students connect their intuitive understanding of these concepts to effectively solve problems.

During the applying intuition stage, students use steps or solutions to solve the target problem, which is derived from the source problem. Students with intuition successfully apply the concept of simple equivalent proportions to more complex problems. This research also found that intuitive subjects used instinct without carrying out formal proportion calculations to solve problems. According to Utomo *et al.* (2023), intuition students prefer to solve problems using their own method, which they believe is shorter and more accurate, while maintaining a structured approach to problem-solving. Someone's intuition is better at using imagination and innovating (Tieger *et al.*, 2017), intuition gives rise to inspiration and skill in understanding implied information (Francis *et al.*, 2020).

Implications of Research

The research can be used as material or a reference in implementing differentiated learning. To achieve maximum learning outcomes, it is important to consider the analogical reasoning of different students, particularly those influenced by sensing-intuition personality factors. You can provide real examples and concrete

exercises to sensing students. Provide visual aids such as diagrams, pictures, or illustrations. This stage allows for increased practice in connecting and applying concepts. For intuition students, they can use questions that challenge creativity. Use these questions to learn about concept exploration. This research can be used as a reference for conducting similar research. Further research can delve into other factors that impact analogical reasoning, investigate alternative materials, and experiment with different methods. This research can also serve as a foundation for the development of teaching materials and learning media tailored to the sensing-intuition personality type, with the goal of enhancing the analogical reasoning skills of sensing students and fostering the analogical reasoning skills of intuition students.

Limitations

The scope of this research is limited to identifying the analogical reasoning process of class VII students with sensing and intuition personality types in relation to proportion material. Therefore, the results of this study may not apply to other mathematics materials or other subjects outside mathematics. We conducted this research with a limited number of subjects. The generalizability of the research results to a broader population may be limited, as the selected subjects may not accurately represent all the characteristics of students with sensing and intuition personalities. The results may not reflect the characteristics of students from other schools or areas. The study did not consider changes in personality or analogical reasoning abilities that may occur over time. Students may show different personality characteristics or analogical reasoning at different times.

CONCLUSION

The research and analysis reveal that students' analogical reasoning on proportional material aligns with their sensing and intuition personalities. Students with sensing and intuition personalities show differences in carrying out analogical reasoning on proportion material. Sensing students carry out the encoding stage by identifying all the information in the source and target problems involving production quantities, number of machines, and production times. They also perform the inferring stage by solving source problems, recognizing material similarities, and understanding the context of snack production problems. However, students require assistance during the mapping and application phases. During the mapping stage, students often concentrate on concrete and specific details, failing to recognize the connection between abstract solutions. Consequently, they struggle to connect the concept of solving the source problem to the target problem. During the sensing stage, it failed to apply the solution concept to the target problem. Meanwhile, students with intuitive personalities carry out the four stages of analogical reasoning: encoding, inferring, mapping, and applying. At the encoding stage, they identified information despite the unclear presentation. During the inferring stage, we determine the source problem, which involves comparing two elements. At the mapping stage, students' intuition connects the steps in solving the source problem to the target problem. At the application stage, students successfully apply proportion concepts from source problems to more complex target problems, demonstrating creativity and becoming innovative problem-solvers.

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Problem-Solving in Geometry Teaching for Pre-service Mathematics Teacher Students from a Computational Thinking Perspective

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Abstract

Computational thinking and problem-solving skills are necessary for the future careers of pre-service mathematics teacher students in the 21st century. This study aims to analyse problem-solving activities in geometry teaching and corresponding assessment for pre-service mathematics teacher students from a computational thinking perspective. To do so, we carried out a qualitative case study through teaching and learning observations involving 41 pre-service mathematics teacher students from one of the state universities in West Java, Indonesia. In this study, 6 x 50 minutes of geometry teaching were observed, and written work containing problem-solving processes retrieved from the formative assessment was analysed from the computational thinking perspective. The results showed that two types of problem-solving activities are identified from the teaching and learning processes and the corresponding assessment, i.e., problem to find and problem to prove. We view that a problem to prove can typically be considered as a structured problem to find. Both types of problems can be fruitfully analysed using Polya's problem-solving strategy from the computational thinking perspective. For future research, we recommend investigating each type of problem using more specific characteristics of computational thinking.

Keywords: *Computational Thinking; Geometry Teaching and Learning; Pre-service Mathematics Teacher Students; Problem-Solving*

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Abstrak

Keterampilan berpikir komputasi (computational thinking) dan pemecahan masalah diperlukan untuk karir masa depan mahasiswa calon guru matematika di abad ke-21. Penelitian ini bertujuan untuk menganalisis aktivitas pemecahan masalah dalam proses pembelajaran geometri dan asesmennya untuk mahasiswa calon guru matematika dari perspektif berpikir komputasi. Untuk itu, kami melakukan studi kasus kualitatif melalui observasi proses pembelajaran yang melibatkan 41 mahasiswa calon guru matematika dari salah satu universitas negeri di Jawa Barat, Indonesia. Dalam penelitian ini, kami mengobservasi pembelajaran geometri untuk calon guru matematika selama 6 x 50 menit, dan hasil tes tertulisnya yang berisi proses pemecahan masalah yang dianalisis dari perspektif berpikir komputasi. Hasil penelitian menemukan adanya dua jenis tipe pemecahan masalah, yang diidentifikasi dari pengamatan proses pembelajaran dan penilaian formative, yaitu masalah tipe menemukan dan masalah tipe membuktikan. Kami memandang bahwa masalah tipe membuktikan sebagai masalah terstruktur dari tipe menemukan. Kedua tipe masalah tersebut dapat dianalisis dengan baik menggunakan strategi pemecahan masalah Polya dari perspektif berpikir komputasi. Untuk penelitian mendatang, kami merekomendasikan untuk menelaah lebih lanjut setiap tipe masalah dengan menggunakan karakteristik berpikir komputasi yang lebih spesifik.

INTRODUCTION

Problem-solving is considered one of the skills that need to be mastered to live in the 21st century (English & Sriraman, 2009; Kemdikbud, 2017). Pre-service mathematics teacher students need to master problem-solving skills as preparation for their future careers, both in the academic world as mathematics teachers and in social life as citizens (De Lange, 2006; Widana, 2017). This problem-solving skill can be developed, among others, through learning geometry topics (Budhi & Kartasmita, 2015; Jupri & Rosjanuardi, 2020; Jupri et al., 2020).

However, problem-solving skills in geometry topics are still not fully mastered by most pre-service mathematics teacher students in Indonesia. Previous research results showed that the problem-solving abilities of pre-service mathematics teacher students in Indonesia in geometry still need to be improved (Jupri, et al., 2020). Yuwono (2016) found that pre-service mathematics teacher students still had difficulty solving problems regarding the use of the concept of triangle congruence and the process of proving the area of triangles and quadrilaterals. Samo (2017) found that the problem-solving proficiencies of pre-service teacher students in geometry are relatively di-

verse and tend to be low for most students. In other research, pre-service mathematics teacher students were considered to have relative difficulty in solving simple geometric problems (Masfingatin et al., 2018).

The findings above are an indication of the necessity to enhance the quality of geometry teaching for pre-service mathematics teacher students. Enhancing the quality of geometry teaching can be conducted, for instance, in the form of improving the quality of teaching materials for students and improving the teaching process which provides wider opportunities for students to do problem-solving processes. The latest research results suggest that aspects of problem-solving proficiencies can be developed better, in line with developments in the current industrial revolution 4.0 era, by integrating computational thinking (CT) skills both in the development of teaching materials and their implementation in learning and teaching processes (Kallia et al., 2021; Van Borkulo et al., 2021; Wing, 2006; 2010). Computational thinking is a process and way of thinking in formulating problems so that the solution can be shown in a form that can be understood by humans, computers, or both (Denning, 2009; Wing, 2006; 2010). This means that CT emphasizes problem-solving processes that can be carried out by humans themselves or

with the help of computers, such as through the use of software, or a combination of the two.

Considering that the meaning of CT is not restricted only to the field of computer science, experts in the field of mathematics education (such as Van Borkulo *et al.*, 2021; Kallia *et al.*, 2021; Sung *et al.*, 2017) have attempted to integrate the idea of CT in the field of mathematics education. For example, Calculus teaching in the Netherlands has been implemented by integrating CT aspects into the learning process. The integration process is done by using the GeoGebra software (Van Borkulo *et al.*, 2021). This integration process was carried out to make CT accessible to teachers and students, and in the future can be applied in everyday situations, the academic world, or the world of work.

Several aspects of CT which are characteristics of a way of thinking and can be integrated into mathematics education include problem decomposition, pattern recognition, abstraction, and algorithms (Kallia *et al.*, 2021; Voogt, 2015). Decomposition is a way of thinking in describing a problem so that it can be separated into smaller sub-problems, and then a relatively more efficient solution can be found. Pattern recognition is a way of thinking in identifying similarities, regularities in data, or recurring phenomena. Abstraction is a way of thinking in generalizing a principle into a formula or rule by modelling the patterns found. The abstraction process can also be interpreted as an activity of looking for the essential parts of a problem and neglecting the unimportant ones, making it easier to focus on the solution to the problem. Finally, the algorithm is a thinking process in compiling steps to solve a problem so that it becomes more systematic and efficient. If examined carefully, these four aspects of Computational Thinking (CT) are in line

with the steps of problem-solving proposed by Polya (1973).

The steps of the problem-solving process according to Polya (1973) include understanding the problem, devising a plan, carrying out the plan, and looking back. In the first step, understanding the problem, we need to specify the known data, the unknown, and the condition of the problem. In the second step, devising a plan, we should relate between the unknown and the known data and should provide problem-solving strategies to solve the problem. From a CT perspective, the first and second steps can be supported by the process of decomposition, pattern recognition, and abstraction. In the third step, carrying out the plan, we should resolve the problem by applying problem-solving strategies provided in the aforementioned step. Finally, in the fourth step, looking back, we need to consider whether the solution that we found makes sense or not, whether we can solve the problem using other problem-solving strategies, and whether we can generalize the problem-solving process for other similar problems. From a CT perspective, the third and fourth steps can be supported by the process of algorithms, abstraction, and decomposition.

Taking the previous description into account, this research aims to analyse problem-solving activities in a geometry learning and teaching process for pre-service mathematics teacher students from the computational thinking perspective. Through this research, it is expected that the results will be useful for improving the quality of the process and results of geometry teaching which can develop the problem-solving abilities of pre-service mathematics teacher students.

METHOD

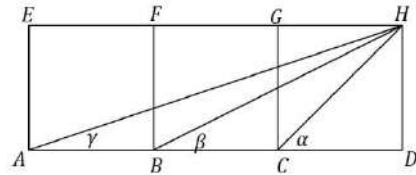
To investigate problem-solving activities in a geometry teaching and learning process, we conducted a qualitative case study through classroom observations on the teaching and learning processes with the following three steps. Firstly, we carried out classroom observations in a geometry course for two meetings (6x50 minutes), involving 41 pre-service mathematics teacher students in one of the state universities in West Java, Indonesia. The participants were in the second year of the mathematics education program. They had learned the foundation of mathematics, calculus, linear algebra, number theory, and statistics. Therefore, we assume that they have already enough experience in doing proof and problem-solving in mathematics. In the observations, we investigated the learning and teaching process for the topic of similarity of triangles, its application in the problem-solving of geometry, and its corresponding written assessment. The focus of teaching observations was on the learning process and the problem-solving activities performed by the lecturer and pre-service mathematics teacher students during the teaching and learning.

Secondly, we administered a formative individual written assessment after the teaching and learning processes. For this formative assessment, two geometry tasks were used (see Table 1). Both tasks ask for proving processes using the concepts of similarity of triangles. The individual written test was administered for about 40 minutes to 41 pre-service mathematics teacher students.

Table 1. Tasks used in the assessment

| No | Tasks |
|----|--|
| 1. | Draw a right triangle $\triangle ABC$. $\angle ACB$ is a right angle, $BC = a$, $AC = b$, $AB = c$ and \overline{CD} is the altitude of the triangle. Prove each of the following statements: |

| No | Tasks |
|----|---|
| | $\triangle ABC \sim \triangle ACD$ $\triangle ABC \sim \triangle CBD$ $a^2 + b^2 = c^2$. |
| 2. | Given a three series of the same squares as shown. Prove that $\alpha = \beta + \gamma$. |



Thirdly, data analysis was carried out. For analysing the learning and teaching process data, we used the framework of problem-solving heuristic strategies (Polya, 1973) from the perspective of Computational Thinking (CT). Similarly, for analysing the written test data, we also used the framework of Polya’s problem-solving strategy from a CT perspective.

RESULTS AND DISCUSSION

Results of Learning and Teaching Observations

The process of learning and teaching the topic of similarity of two triangles was started by the lecturer by asking pre-service mathematics teacher students about this topic which had been studied when they were studying at junior high school level. After questions and answers, the lecturer wrote and explained the definition of the similarity of two triangles, wrote and explained the theorems of the similarity of two triangles, namely the SAS (Side-Angle-Side) theorem, the AAA (Angle-Angle-Angle) theorem, and the SSS theorem (Side-Side-Side). As an illustration of the use of the rules for the similarity of two triangles, the lecturer gave two example problems. The first example problem discussed in the learning process is as follows: “Given an acute triangle ABC . The point P is on \overline{AC} and Q is on \overline{BC} such

that $\overline{PQ} \parallel \overline{AB}$. Prove that $\frac{CP}{PA} = \frac{CQ}{QB}$."

The process of proving, guided by the lecturer through questions and answers as well as explanation, was carried out as follows. Let the acute triangle be ABC . With some information given in the problem, the triangle is constructed as in Figure 1.

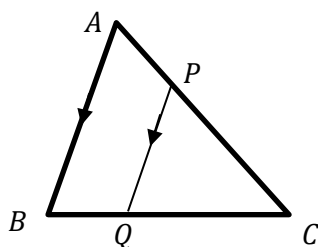


Figure 1. The triangle ABC and its information

Since $\overline{PQ} \parallel \overline{AB}$, then we have $\angle CPQ \cong \angle CAB$, and $\angle CQP \cong \angle CBA$. Also, it is obvious that $\angle PCQ \cong \angle ACB$. As a consequence, according to the theorem of AAA (Angle-Angle-Angle), we conclude $\triangle CPQ \sim \triangle CAB$. Because $\triangle CPQ \sim \triangle CAB$, then we have the following relation:

$$\frac{CP}{CA} = \frac{CQ}{CB}.$$

$$\Leftrightarrow \frac{CP}{CP+PA} = \frac{CQ}{CQ+QB}.$$

$$\Leftrightarrow \frac{CP+PA}{CP} = \frac{CQ+QB}{CQ}.$$

$$\Leftrightarrow 1 + \frac{PA}{CP} = 1 + \frac{QB}{CQ}.$$

$$\Leftrightarrow \frac{PA}{CP} = \frac{QB}{CQ}.$$

$$\Leftrightarrow \frac{CP}{PA} = \frac{CQ}{QB}.$$

Based on the observation of the teaching episode above, we have the following notes. Regarding the explanation process for proving the first example problem above, we view that the lecturer explains the steps for the proving process according to Polya's problem-solving

strategy and the perspective of Computational Thinking (Van Borkulo et al., 2021; Gadanidis et al., 2017; Kallia et al., 2021; Polya, 1973; Sung et al., 2017). The ability to understand and identify problems can be seen as the application of the decomposition aspect. The ability to devise a plan in the form of creating appropriate visualizations, by describing the information and information given in the problem correctly, can be seen as the application of aspects of pattern recognition and abstraction. The ability to apply rules of the similarity of triangles, as well as simple algebraic manipulation, are aspects of algorithms. Thus, again it can be said that the process of problem-solving in the form of a proving process is an implementation of the aspects of Computational Thinking (CT).

The second example problem discussed during the teaching and learning process is as follows: "Given a right triangle PQR where $\angle QPR$ is the right angle. If $PQ = 3$ cm, $PR = 4$ cm, and PS is perpendicular to QR , then find the lengths of PS , QS , and RS ."

The problem-solving process for the second example problem was also guided by the lecturer as follows. From the given information, we can construct Figure 2 below.

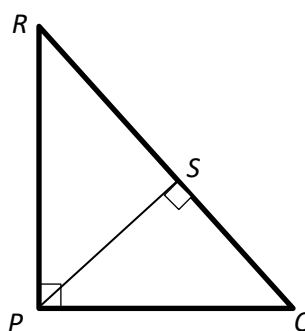


Figure 2. The triangle PQR and its information

Using the Pythagoras' theorem on the triangle PQR , we find that $QR = 5$ cm. Next, by using the AAA (Angle-Angle-Angle) theorem the lecturer verbally showed

that $\Delta PQR \sim \Delta SPR$, $\Delta PQR \sim \Delta SQP$, and $\Delta SQP \sim \Delta SPR$.

From $\Delta PQR \sim \Delta SPR$, we have the relation $\frac{PQ}{SP} = \frac{QR}{PR}$. This implies that $SP = \frac{PQ \cdot PR}{QR}$. By substitutions of the given information, we have $SP = PS = \frac{12}{5}$ cm.

From $\Delta SQP \sim \Delta SPR$, we have the relation $\frac{SQ}{SP} = \frac{QP}{PR}$. This implies that $SQ = \frac{QP \cdot SP}{PR}$. By substitutions of the lengths from the given information and the previous result, we have $SQ = QS = \frac{9}{5}$ cm.

From $\Delta PQR \sim \Delta SPR$, we have the relation $\frac{PR}{SR} = \frac{QR}{PR}$. This implies that $SR = \frac{PR \cdot PR}{QR}$. By substitutions of the lengths from the given information, we have $SR = RS = \frac{16}{5}$ cm.

Concerning the observation of the second example problem above, we have the following notes. We clearly view that the lecturer in guiding the problem-solving has used Polya's strategy and computational thinking characteristics. When the lecturer showed verbally the similarity between two triangles repeatedly to obtain $\Delta PQR \sim \Delta SQP$, $\Delta PQR \sim \Delta SPR$, and $\Delta SQP \sim \Delta SPR$, he decomposed the problem into three similarities of triangles (Kallia et al., 2021; Van Borkulo et al., 2023). Next, when he repeatedly uses the proportional relations from the similarity of triangles to find the lengths of segments, this means he has used algorithmic thinking meaningfully (Gadanidis et al., 2017; Van Borkulo et al., 2023). Also, when the lecturer creates the visualization from the given problem, it concerns the application of aspects of pattern recognition and abstraction (Gadanidis et al., 2017; Kallia et al., 2021; Van Borkulo et al., 2023). Therefore, we identify that the process of problem-solving in the form of applying the similarity of triangles concepts is the implementation of computational

thinking.

Whereas the first example concerns the proving problem of the similarity of triangles, the second example concerns the problem-solving by applying the concepts of the similarity of triangles. In our view, both types of problems need problem-solving strategies which can be seen from the perspective of computational thinking (CT). In this case, the aspects of CT play crucial roles in each step of the problem-solving heuristics strategy.

Results of Written Assessment

Table 2 presents the findings from pre-service mathematics teacher students' written work on solving proving problems for the topic of the similarity of triangles. The results for Task 1 are relatively better than for Task 2. In general, however, we view that both tasks are relatively difficult for most of the participants.

Table 2. Results of the assessment (n =41)

| Tasks | #Correct(%) |
|---|--|
| 1. Draw a right triangle ΔABC . $\angle ACB$ is a right angle, $BC = a$, $AC = b$, $AB = c$ and \overline{CD} is the altitude of the triangle. Prove each of the following statements: (a) $\Delta ABC \sim \Delta ACD$ (b) $\Delta ABC \sim \Delta CBD$ (c) $a^2 + b^2 = c^2$. | (a). 32 (78.1) (b). 33 (80.5) (c). 18 (43.9) |
| 2. Given a three series of the same squares as shown. Prove that $\alpha = \beta + \gamma$. | 15(36.6) |

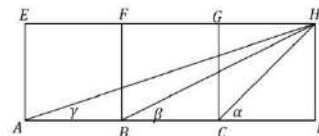


Figure 3 (in Appendix A) shows an example of correct answers for Task 1 parts (a), (b), and (c). The main objective for Task 1 is proving the Pythagoras' theorem using the concepts of the similarity of triangles. To reach this objective, this

task has been divided into three questions. Parts (a) and (b) are used to get part (c). From a CT perspective, this task directly guides students through decomposing the problem into parts (a) and (b) (Kallia et al., 2021; Zhang & Nouri, 2019).

Tasks 1(a) and 1(b) concern finding and proving two similar triangles. The first step that must be done is drawing a right triangle and the given information. We found that all participants did this correctly. The second step for solving either part (a) or (b) is applying the AAA (Angle-Angle-Angle) theorem to prove $\Delta ABC \sim \Delta ACD$, $\Delta ABC \sim \Delta CBD$, and $\Delta ACD \sim \Delta CBD$. Proving each of these similarities concerns the use of the step-by-step process, which from the CT perspective is included within the algorithm aspect (Kallia et al., 2021; Katai, 2020; Van Borkulo et al., 2023). We found that the difficulties encountered by the participants in dealing with Task 1 part (a) or (b) include finding corresponding angles between two triangles that have the same measures. As a consequence, they were not able to prove the similarities of $\Delta ABC \sim \Delta ACD$, $\Delta ABC \sim \Delta CBD$, and $\Delta ACD \sim \Delta CBD$.

Task 1(c) requires students to prove Pythagoras' theorem using the concept of similarities of triangles. To do so, parts 1(a) and 1(b) should be used for solving Task 1(c) as follows. Because $\Delta ABC \sim \Delta ACD$, then we have the relation $\frac{AC}{AD} = \frac{AB}{AC}$ or $AC^2 = AB \cdot AD$. Because $\Delta ABC \sim \Delta CBD$, then we have the relation $\frac{BC}{BD} = \frac{AB}{CB}$ or $BC^2 = AB \cdot BD$. By adding these last two results, we obtain $BC^2 + AC^2 = AB \cdot BD + AB \cdot AD = AB^2$. From a CT perspective, to be able to prove the Pythagoras' theorem in Task 1(c), we need abstractive skills that synthesize previous results (Lv et al., 2022; Van Borkulo et al., 2023).

Figure 4 (in Appendix B) illustrates a

correct answer for Task 2. Similar to the previous task, Task 2 also asks for participants to do a proving process. However, as indicated by the written test results in Table 2, this task is more challenging than Task 1. The difficulties found in written student work mainly concerns, for instance, finding similarities between triangles for proving the required property of $\alpha = \beta + \gamma$.

In our view, from the CT perspective, the ability to see and prove $\Delta ACH \sim \Delta HCB$ using the SAS (Side-Angle-Side) theorem (see Figure 4) needs not only algorithmic skills but also abstractive skills (Kallia et al., 2021; Sanford, 2018).

Discussion

From the results section, we note the following three points to discuss. First, problem-solving activities for the topic of the similarity of triangles for pre-service mathematics teacher students that can be identified from teaching observations can be classified into problem-solving to prove and problem-solving to find (see Polya, 1973). Problem-solving to prove means the activity of proving statements, properties, or theorems. Problem-solving to find means the activity of finding a solution to a non-routine problem. We view that problem-solving to prove can be seen as a structured problem-solving to find. From a CT perspective, both types of problem-solving involve CT aspects, including decomposition, abstraction, and algorithm (Kallia et al. 2021; Van Borkulo et al., 2023). The CT aspects involve the implementation of problem-solving heuristic strategies, for instance in the steps of devising a plan, carrying out the solution process, and looking back.

Second, the teaching and learning process for pre-service mathematics teacher students for the topic of similarity

of triangles can be classified into a deductive teaching approach (Ndemo et al., 2017; Prince & Felder, 2006). The process starts from general ideas of the topic in the form of addressing definitions and proving theorems to more specific ideas in the form of discussing example problems through questions and answers. In our view, even if the deductive characteristics are dominant, still the lecturer provides room for students to be involved during the teaching and learning process through questions and answers.

Third, difficulties encountered by the participants that emerged in written work include identifying similarities between two triangles, applying the similarities theorems for the proving process, and executing algebraic manipulations to obtain the required results. From a CT perspective, these difficulties indicate that pre-service mathematics teacher students are struggling with decomposing, synthesising, abstracting, and thinking algorithmically when solving geometry problems (see Futschek, 2006; Kallia et al., 2021; Kynigos & Grizioti, 2018).

Implication of Research

Regarding the finding of two types of problem-solving activities, we wonder whether these two types can be compared to which one is more challenging and requires computational thinking aspects during the problem-solving processes. This might be an opportunity to be investigated in the learning and teaching processes and future research.

Concerning the usage of the deductive teaching approach in the learning and teaching process, which has a more lecturer-centred approach, for future research we wonder if the student-centred approach would produce better results for improving the skills of problem-solving

and computational thinking. Many studies (such as Hino, 2007; Ridlon, 2009) suggest that a student-centred approach can enhance problem-solving skills. In addition, we do wonder whether the main aspects of CT can be applied to enhance problem-solving abilities, particularly in the topic of geometry.

With regard to encountered difficulties during problem-solving activities for the topic of similarity of triangles, we do wonder a more comprehensive repertoire on this. For future studies, it is worth exploring possible difficulties encountered by pre-service mathematics teacher students in dealing with problem-solving on the topic of the similarity of triangles.

Limitation

We admit that this study has several limitations. First, since this study focused only on the results of classroom observations for the topic of the similarity of triangles and written work from the formative assessment, we are aware that the results of the study might be more comprehensive if additional interview data are incorporated. Also, more comprehensive results might be obtained if observations are carried out for more than one cohort of pre-service mathematics teacher students.

Second, three main CT aspects, namely decomposition, abstraction, and algorithm played crucial roles in interpreting problem-solving activities from both observations and written work. However, the aspect of pattern recognition does not emerge explicitly. This probably is caused by the fact that problem-solving in the forms of problem to prove, which are apparently dominant in the observations, does not provide an explicit opportunity to recognize patterns. Probably, in the future, it is necessary to add problems to find or problems to prove that require explicit recognition of patterns when doing

problem-solving activities. Other CT aspects that might emerge and should be exploited include mathematical modelling which plays a crucial role in dealing with problem-solving on word or contextual problems.

CONCLUSION

From the previous sections, we draw the following conclusions. Based on the observations of the learning and teaching process for pre-service mathematics teacher students on the topic of the similarity of triangles, we found two types of problem-solving activities. These types include problems to prove and problems to find. We consider that both types of problems can be fruitfully analysed using Polya's problem-solving strategy from the computational thinking perspective. Three main CT aspects play crucial roles in the interpretation of problem-solving activities, including decomposition, abstraction, and algorithm aspects. These aspects are used to interpret problem-solving heuristic strategies used in the learning and teaching process and written student work. In the future, we consider investigating other CT aspects for interpreting problem-solving activities for either problem to prove or problem to find.

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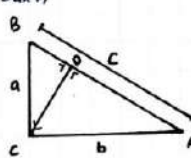
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Appendix A of article entitled Problem-Solving in Geometry Teaching for Pre-service Mathematics Teacher Students from a Computational Thinking Perspective

Gambarkanlah $\triangle ABC$ siku-siku di C , dengan $\overline{BC} = a$, $\overline{AC} = b$, $\overline{AB} = c$ dan \overline{CD} adalah garis tinggi. Buktikan bahwa

(a) $\triangle ABC \sim \triangle ACD$
 (b) $\triangle ABC \sim \triangle CBD$
 (c) $a^2 + b^2 = c^2$

bukti



(a) Perhatikan bahwa
 $m\angle ACB \cong m\angle ADC$ (siku-siku)
 $m\angle CAB \cong m\angle DAC$ (berimpit)
 $m\angle ABC \cong m\angle ACD$ (besarannya sama hasil dari $180^\circ - (90^\circ + \angle A)$)
 Menurut aturan AAA, maka terbukti
 $\triangle ABC \sim \triangle ACD$

(b) Perhatikan bahwa
 $m\angle ACB \cong m\angle CDB$ (siku-siku)
 $m\angle ABC \cong m\angle CBD$ (berimpit)
 $m\angle CAB \cong m\angle DCB$ (besarannya sama hasil dari $180^\circ - (90^\circ + \angle B)$)
 Menurut aturan AAA, maka terbukti $\triangle ABC \sim \triangle CBD$

(c) karena $\triangle ABC \sim \triangle ACD$, maka $\frac{AC}{AD} = \frac{AB}{AC}$
 $AC^2 = AB \cdot AD \dots (i)$

Dan karena $\triangle ABC \sim \triangle CBD$, maka $\frac{BC}{BD} = \frac{AB}{CB}$
 $BC^2 = AB \cdot BD \dots (ii)$

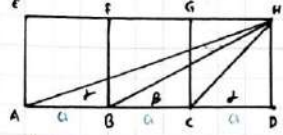
Dari persamaan $AC^2 = AB \cdot AD \dots (i)$ dan $BC^2 = AB \cdot BD \dots (ii)$, maka diperoleh
 $AC^2 + BC^2 = (AB \cdot AD) + (AB \cdot BD)$
 $= AB(AD + BD)$
 $= AB(AB)$
 $= AB^2$

Maka, dapat disimpulkan bahwa $AC^2 + BC^2 = AB^2$ atau $a^2 + b^2 = c^2$
 Jadi, terbukti $a^2 + b^2 = c^2$

Figure 3. Solution to Task 1 from written student work

Appendix B of article entitled Problem-Solving in Geometry Teaching for Pre-service Mathematics Teacher Students from a Computational Thinking Perspective

Diketahui rangkaian tiga persegi seperti tampak pada gambar. Buktikan bahwa $\alpha = \beta + \gamma$



bukti:

Misalkan panjang sisi persegi panjang adalah a satuan panjang
maka, $\overline{CH} = a\sqrt{2}$

Perhatikan bahwa

$$\frac{CH}{CB} = \frac{AC}{HC} \Leftrightarrow \frac{a\sqrt{2}}{a} = \frac{2a}{a\sqrt{2}} \text{ dan}$$

$$m\angle ACH = m\angle HCB \text{ (reflektif)}$$

Akibatnya bahwa $\triangle ACH \sim \triangle HCB$ dan diperoleh bahwa $m\angle CHB = m\angle CAH = \gamma$

Perhatikan $\triangle HCB$, bahwa

$$m\angle BCH + m\angle BHC + m\angle CBH = 180^\circ$$

$$\Leftrightarrow 180^\circ - \alpha + \gamma + \beta = 180^\circ$$

$$\Leftrightarrow \alpha = \beta + \gamma \text{ terbukti benar}$$

Figure 4. Solution to Task 2 from written student work



Exploration of Mathematical Communication Skills of Students with Mild Intellectual Disability Through Manipulative Activities Using Bowls and Marbles

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Abstract

This study identified students' mathematical understanding and communication deficiencies, especially in dividing numbers. Although bowls and marbles have been used to support mathematical conceptual understanding, there are limitations in understanding how students communicate effectively about division and numbers in practical contexts. This study explores students' mathematical communication skills in dividing and counting and how using bowls and marbles influences this. The research method used is a case study with a qualitative approach involving direct observation and video recording. The study subjects comprised four students with mild intellectual disabilities and different characteristics in communicating and understanding mathematical concepts. The instruments used included observation notes and video recordings of learning. Data were collected through observation of the learning process and video analysis to assess communication skills and conceptual understanding. The results showed that students 1 and 2 had better mathematical communication skills and a strong understanding of division, although with some initial errors. Students 3 and 4 highly depended on teacher direction and were less active in verbal communication. This study concludes that using bowls and marbles can improve understanding of division, but the success of mathematical communication is greatly influenced by active student involvement and teacher direction. This study implies the need to develop more interactive learning strategies and additional support for students with difficulties in mathematical communication. Applying teaching techniques emphasizing active student involvement and effective use of bowls and marbles can improve understanding of mathematical concepts and communication skills.

Keywords: communication skills, division, use of bowls and marbles, mathematical concepts

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Abstrak

Penelitian ini mengidentifikasi kekurangan dalam pemahaman dan komunikasi matematis siswa, terutama dalam konteks pembagian bilangan. Meskipun bowls and marbles telah digunakan untuk mendukung pemahaman konsep matematis, terdapat keterbatasan dalam memahami bagaimana siswa berkomunikasi secara efektif mengenai pembagian dan membilang dalam konteks praktis. Penelitian ini bertujuan untuk mengeksplorasi kemampuan komunikasi matematis siswa dalam konteks pembagian dan membilang serta bagaimana hal ini dipengaruhi oleh penggunaan mangkok dan kelereng. Metode penelitian yang digunakan adalah studi kasus dengan pendekatan kualitatif, melibatkan observasi langsung dan rekaman video. Subjek penelitian terdiri dari empat siswa tunagrahita ringan dengan karakteristik berbeda dalam berkomunikasi dan memahami konsep matematika. Instrumen yang digunakan meliputi catatan observasi dan rekaman video pembelajaran. Data dikumpulkan melalui observasi proses pembelajaran dan analisis video untuk menilai kemampuan komunikasi dan pemahaman konsep. Hasil penelitian menunjukkan bahwa siswa 1 dan siswa 2 memiliki kemampuan komunikasi matematis yang lebih baik dan pemahaman yang kuat mengenai pembagian, meskipun dengan beberapa kesalahan awal. Siswa 3 dan siswa 4 menunjukkan ketergantungan yang tinggi pada arahan guru dan kurang aktif dalam komunikasi verbal. Kesimpulan dari penelitian ini adalah bahwa media manipulatif dapat meningkatkan pemahaman pembagian, namun keberhasilan komunikasi matematis sangat dipengaruhi oleh keterlibatan aktif siswa dan arahan guru. Implikasi dari penelitian ini adalah perlunya pengembangan strategi pembelajaran yang lebih interaktif dan dukungan tambahan bagi siswa yang menunjukkan kesulitan dalam komunikasi matematis. Penerapan teknik pengajaran yang menekankan pada keterlibatan siswa secara aktif dan penggunaan media manipulatif yang efektif dapat meningkatkan pemahaman konsep matematis dan keterampilan komunikasi.

INTRODUCTION

Mathematics is essential to everyday life, crucial in decision-making, problem-solving, and developing critical thinking skills. Its relevance extends beyond the academic space, manifesting in activities such as managing budgets, shopping, or planning activities, which require a basic understanding of mathematical concepts (Marasabessy, 2021). This practical application of mathematics supports financial literacy and improves an individual's ability to solve problems systematically (Angraini et al., 2023).

In education, the importance of mathematics is often illustrated through an approach that connects abstract concepts with real contexts. One effective approach is Realistic Mathematics Education (RME), which has been shown to increase student engagement by linking mathematical problems to everyday experiences (Rahayu et al., 2021). This approach confirms that mathematics is an abstract discipline and a practical tool for life (Hendrayanto et al., 2022). One way that can be used to bridge the abstract of

mathematics is with manipulative activities.

Manipulative activities, defined as using concrete or virtual objects to aid students in understanding and solving abstract mathematical concepts, are particularly beneficial for students with disabilities, including those with intellectual disabilities. These manipulatives are essential tools that facilitate the transition from concrete experiences to abstract reasoning in mathematics. Research indicates that manipulatives can significantly enhance students' engagement and comprehension in mathematical tasks by providing tangible representations of abstract concepts (Carbonneau et al., 2013; Peltier et al., 2020; Spooner et al., 2019). For instance, Spooner et al. (2019) highlight that manipulatives can help students with moderate to severe developmental disabilities grasp complex mathematical ideas more effectively.

A critical aspect of this process is mathematical communication, which bridges abstract mathematical concepts and practical applications. As the educational landscape evolves, the emphasis on

communication skills has become increasingly pronounced, reflecting the need for students to articulate their mathematical reasoning effectively. Mathematical communication is a core skill that helps students connect mathematical concepts with practical applications. This communication includes conveying, interpreting, and reasoning about mathematical ideas through verbal, written, or visual forms (Aladwan et al., 2023; Ambarwati & Darmawati, 2020). Good mathematical communication skills indicate the ability to compose logical explanations, interpret mathematical information accurately, and convey ideas coherently. These skills deepen students' understanding and increase collaboration and engagement in learning (Sholihah et al., 2022).

For students with intellectual disabilities, mathematical communication is a challenge and an important need (Muchyidin & Priatna, 2022). Their main obstacle often involves difficulty understanding and expressing mathematical concepts due to cognitive and language limitations (Dalilan et al., 2021). This challenge is exacerbated by cognitive inertia, which is difficulty changing mindsets when faced with new concepts and semantic barriers, such as understanding abstract mathematical terms (Agheana, 2023; Root et al., 2017). Therefore, customized teaching strategies are indispensable to support student understanding and communication.

Instructional approaches such as Virtual–Representational–Abstract (VRA) and Concrete–Representational–Abstract (CRA) have proven effective in supporting mathematics learning for students with intellectual disabilities. The VRA model helps students understand abstract concepts through cascading stages, from visual manipulation of concrete representation to symbolic abstraction (Bouck et al.,

2018; Bouck & Bone, 2018). Meanwhile, the CRA model integrates physical manipulation, visual representation, and mathematical symbols to build a deep understanding of the concept (Bouck et al., 2020; N. M. Sari et al., 2020). This approach also provides opportunities for students to practice mathematical communication skills through various forms of expression.

This research focuses on how students with intellectual disabilities communicate their understanding of division. Division is a fundamental arithmetic operation that improves computational skills and encourages critical thinking and problem-solving skills. For students with intellectual disabilities, understanding the concept of division becomes an essential skill to support daily functions, such as dividing goods or allocating resources equitably.

Through direct observation, this study aims to uncover the strategies used by students in understanding and conveying the concept of division, as well as how they overcome communication challenges in the learning process. By studying emerging indicators of mathematical communication skills, this research is expected to provide new insights that can be used to develop inclusive and effective learning strategies for students with intellectual disabilities.

METHOD

The qualitative research method (Creswell, 2014) focuses on understanding how students with mild intellectual disabilities communicate their comprehension of mathematics, specifically the concept of division. The study subjects were four students with mild intellectual disabilities, selected based on the research criteria. The research was conducted using observational methods, with the material

taught being division concepts using bowls and marbles as concrete aids. This approach was chosen to support students in visualizing and articulating their understanding of division.

The role of the researcher as an observer began with a collaborative discussion with the classroom teacher to determine the roles and materials to be delivered to the students. Classroom teachers were assigned to teach as usual to minimize adaptation needs, ensuring that communication between students and the teacher remained optimal. By keeping the teaching consistent, the researcher could focus on observing how students verbally communicated their understanding of division without the added variable of new instructional methods.

The researcher observed every moment in the classroom during the learning process, recording how students interacted with the materials and responded to instructions. This direct observation allowed the researcher to gather real-time insights into how students expressed their comprehension of division. Additionally, the researcher guided students who had difficulty understanding the teacher's instructions, ensuring that students could still actively participate in the learning process.

The study's primary objective—to explore how students communicate their understanding of division—was supported by having the teacher demonstrate the division process, followed by students independently performing the task. This structure allowed the researcher to observe how students verbally articulated their process and challenges, providing valuable data on their communicative and cognitive approaches to understanding division.

Participants

The subjects in this study are four students with mild intellectual disabilities from a private school in Bandung. The subjects of this study were selected based on inclusion criteria, namely students with mild intellectual disabilities. From nine students in class X at SLB, a selection was made to determine students who met this criterion so that the research subject was relevant to the study's focus. The school is near a traditional market, influencing the students' daily environment and community interactions. The socioeconomic conditions of the students' families are generally from economically disadvantaged backgrounds, which affects their access to educational resources and support. The student's learning habits and needs are shaped by their circumstances and the resources available at their school, providing a unique context for this study.

Instruments

The primary instruments used in this study include observation notes and educational materials specifically designed for teaching division. The educational materials consist of bowls and marbles, which serve as concrete aids to help students visualize and understand the concept of division. The observation notes are structured with specific categories to systematically document the students' verbal explanations and actions during the division activities. These categories include students' accuracy in following instructions, verbalizing the division process, and using the materials to demonstrate understanding. Such a design ensures that the notes capture detailed and organized information about how students understand and engage with mathematical concepts.

Data Collection

Data collection is conducted through structured observations of the students as they engage with the division tasks. The process begins with the teacher demonstrating simple division using bowls and marbles to illustrate the concept. After this demonstration, the students are asked to perform similar division tasks independently. The researcher observes and records the students' verbal explanations and actions during these tasks. Observations were conducted over four sessions spread across two weeks, each lasting 60 minutes. To enhance the credibility of the data and minimize potential observer bias, triangulation was applied by cross-referencing observations with video recordings and field notes. Additionally, periodic discussions with the classroom teacher were conducted to validate interpretations of the students' responses and actions. This combination of methods ensured a comprehensive and objective documentation of the students' communication and problem-solving processes.

Data Analysis

Data analysis involves thematic analysis of the collected observation notes and recordings. The researcher reviews the recorded data to identify recurring patterns and critical themes in how students understand and explain division. Data is coded based on categories such as division strategies (e.g., grouping, repeated subtraction), levels of understanding (e.g., concrete, representational, abstract), and verbal communication of mathematical concepts (e.g., accuracy in explaining steps and use of mathematical terms). Potential themes include "effective use of concrete aids," "common errors in division processes," and "barriers to ver-

balizing mathematical ideas." This process also includes identifying specific difficulties faced by the students, such as misunderstanding the concept of equal groups, and effective teaching strategies observed during the sessions. The thematic analysis aims to provide a comprehensive understanding of the student's cognitive and communicative processes in the learning division, contributing to developing more effective instructional methods for students with intellectual disabilities.

RESULTS AND DISCUSSION

Results

In this study, the learning process focused on understanding the concept of division through manipulative activities using concrete objects, namely stars, that must be divided into several bowls. This learning process involves the active role of students with intensive guidance from teachers, especially in counting, sharing, and verbal and non-verbal communication. The following are the details of the stages carried out in the learning process:

Teacher Instruction. The teacher begins the learning by giving clear instructions regarding the division tasks that must be done. These instructions are often delivered verbally and are accompanied by non-verbal cues, such as pointing at a bowl or exemplifying how to do a portion. In some cases, such as in student 3, the teacher must actively point to the correct bowl so that the student can carry out the task appropriately.

Selection of Number of Objects (Stars). The teacher determines the number of stars to be divided, and students are asked to count the number of stars aloud. This process aims to train students' numeracy skills from numbers 1 to 12. Students who are already more fluent, such

as student 1, can count well, while other students, such as student two or student 3, are more likely to use non-verbal gestures, such as counting with their fingers.

Division process. Each student was asked to divide the stars into several bowls based on the instructions given. In divisions such as six divided by 2 or 9 divided by 3, students divide by placing stars individually into the available bowl. Mistakes often occur due to a lack of concentration or understanding of how an even distribution should be made. For example, student one mistakenly placed a star on the wrong bowl because he lost focus, and student 4 refused to participate in the division.

Repetition and Correction. After

each student divides, the teacher will check to ensure the correctness of the results. If there is an error, such as an uneven division, students are asked to recount the number of stars or redivide. This repetition aims to strengthen students' understanding of the concept of division and to improve their consistency in completing tasks.

Clarification and Discussion. Teachers also often ask other students, such as student two or student 4, to verify the results of the division done by student 1. This is a way for teachers to ensure that other students pay attention to and understand the ongoing process. It also provides opportunities for students to ex-

Table 1. Students' ability profiles in the Learning Division

| Indicator | Student 1 | Student 2 | Student 3 | Student 4 |
|--|--|---|--|---|
| Mathematical Communication Skills | Verbal: Able to count from one to ten, but sometimes makes mistakes in counting. | Verbal: Counting in a loud and clear voice, providing the correct answer when asked for clarification. | Verbal: Quiet, not talking much, has difficulty without the teacher's instructions. | Verbal: Uses a clear voice to count and confirm results. |
| | Non-Verbal: Shows confusion and hesitation when dividing stars. | Non-Verbal: Actively corrects mistakes but more often uses non-verbal communication. | Non-Verbal: Follows teacher's instructions well, lacks initiative. | Non-Verbal: Actively helps and corrects other students but is less active in speaking. |
| Counting Ability (1-12) | Able to count from one to ten, makes mistakes with numbers above ten. | Able to count from one to twelve well without significant difficulty. | Able to count from one to twelve according to instructions. | Able to count from one to twelve well. |
| Ability in a division | is often confused and makes mistakes in distributing stars evenly, which needs correction. | Understands division well and can correct mistakes made by other students. | Able to divide stars as instructed, struggles without direct guidance from the teacher. | Understands division well and can confirm correct results. |
| Ability to Express Opinions | Less active in expressing opinions verbally, more focused on practical activities. | Active in expressing opinions and giving corrections, although more often using non-verbal communication. | Rarely expresses opinions and relies on the teacher's instructions to complete tasks. | Tends not to be active in verbal expression but provides clarification when asked. |

press their opinions and practice mathematical communication verbally and through gestures.

Student Reflection and Awareness. In some cases, students realize their mistake, such as when student 1 realizes that his star is lacking in one of the divisions and shows a reaction such as patting his head or laughing. This awareness is crucial because it shows that students are learning from their mistakes and are starting to understand the concept of division better.

Independent Practice. Apart from

the intensive guidance of the teacher, students are also allowed to complete the task independently, as seen when student 1 and student 2 take the initiative to recalculate the stars or divide the stars according to the instructions given. Although some still need correction, this process supports independence and initiative in learning.

All student and teacher activities are recorded for further analysis during the learning process. The recording results obtained important information related to interaction and learning dynamics. Analysis of the recordings showed how

Table 2. Student's ability profile in dividing

| Student | Six divided by 2 | Six divided by 3 | Nine divided by 3 | Ten divided by 2 | Ten divided by 5 | 12 divided by 2 |
|-----------|---|---|--|---|---|---|
| Student 1 | Able to divide stars with some initial confusion but completed it with the teacher's help. | Able to divide with some mistakes in star placement was corrected after guidance. | Made an error in the second round but finished with the teacher's help. | Able to divide but made a mistake in the final count. Realised the error after being guided. | Hesitated in placing stars in the third bowl but succeeded after help from Student 2 and the teacher. | Used the incorrect number of bowls but finished correctly after being directed. |
| Student 2 | Able to count and divide stars correctly, though relied primarily on non-verbal gestures. | Able to divide correctly but is more comfortable with non-verbal communication. | Able to count correctly, though remained silent during the process. | Able to recount correctly, demonstrating good counting skills. | Provided accurate corrections to Student 1's mistakes, showing a good understanding despite speaking very little. | Able to divide stars correctly, though primarily using non-verbal gestures. |
| Student 3 | Able to divide when given explicit instructions from the teacher. | Able to divide with guidance, tend to be passive without instructions. | Required guidance in dividing and waited for the teacher's instructions. | Needed full direction from the teacher but was able to finish after being guided. | Still highly dependent on direct instructions from the teacher, lacks confidence in division. | Able to divide after direct guidance from the teacher, needed assistance to complete. |
| Student 4 | Able to divide but preferred to confirm results from other students rather than actively participate. | Passive in dividing, prefers to confirm existing results. | Correctly confirmed results but was reluctant to participate in the division process actively. | Understands division but is unwilling to take an active role; only confirms results internally. | Able to count and understand division but remains passive and reluctant to engage directly. | More passive, though, can count well. This student avoids active involvement and only confirms results. |

students responded to the teacher's instructions, both verbally and non-verbally, and how they performed the assignment tasks. Mistakes made by students in counting or dividing stars became one of the focuses of the analysis, where some students were seen having difficulty in dividing appropriately, while others were able to correct the mistakes after getting directions from the teacher. This recording also shows teachers' communication strategies in providing guidance, both with words and gestures, which help students understand the concept of division. This analysis shows that students need repetition and clarification in several stages but gradually improve concept understanding and numeracy skills.

Table 1 provides an overview of each student's strengths and areas for improvement based on mathematical communication, arithmetic, division, and expressing opinions.

Table 2 above summarises each student's abilities in various divisions, showing how they interact with the teacher and assignments and how they carry out the division.

Discussion

Key Findings and Analysis

Table 1 shows a significant variation in mathematical communication skills between the four students. Student 1 has limited verbal communication skills, often makes mistakes in counting up to ten, and shows confusion when asked to divide non-verbally. This condition is reflected in Table 2, where Student 1 often makes mistakes in the assignment assignment, such as misplacing stars or bowls, and needs the guidance of teachers and other students to complete the assignment. This indicates that limited verbal and non-verbal communication skills impact the

difficulty of independently understanding and implementing the concept of division.

In contrast, Student 2 displayed good verbal communication skills, although they used non-verbal communication more often. This student can explain the answer clearly when asked, show accuracy in counting up to the twelfth number, and be able to give corrections to other students. In the division task (Table 2), Student 2 showed high accuracy in dividing the stars, although they tended to use non-verbal gestures during the process. This shows that although Student 2 prefers non-verbal communication, his mathematical understanding is quite strong, allowing him to assist other students in completing assignments.

Student 3, on the other hand, showed a high dependence on the teacher's direction in verbal and non-verbal communication. Although they can count up to twelve according to instructions, these students rarely express opinions and are more passive in-class activities. In the division task (Table 2), Student 3 needs explicit guidance for each step. This dependency indicates that a lack of initiative and confidence affects students' ability to communicate mathematical understanding, especially when dealing with independent tasks.

Student 4 also exhibits a unique communication pattern. Despite having enough verbal ability to count up to twelve correctly, these students prefer to validate the results of other students rather than actively participate. This is reflected in the assignment (Table 2), where Student 4 rarely takes an active role, more often confirming the outcome than directly completing the assignment. A preference for passive validation indicates that these students understand the concept of division but may experience barriers to motivation or confidence in actively participating.

From both tables, the ability to calculate directly affects the performance of the division. Student 1, with the limitation of counting above the number of ten, had difficulty distributing the stars evenly. Meanwhile, Student 2, who had good numeracy skills, showed more stable performance in division tasks, although they tended to use non-verbal communication. Students 3 and 4 showed adequate numeracy skills, but their dependence on teachers (Student 3) and lack of initiative (Student 4) limited their effectiveness in completing division tasks independently.

The ability variation between students emphasizes the importance of an individualized approach to mathematics learning for students with mild intellectual disabilities. Student 1 needs more intensive support, such as strengthening verbal communication skills and dividing tasks into small steps to reduce confusion. For Student 2, strategies that encourage verbal expression more often can help improve the balance between verbal and non-verbal communication. Student 3 will benefit from independence training through step-by-step instruction designed to reduce reliance on teachers. Student 4, on the other hand, needs additional motivation to increase active participation, such as positive reinforcement or giving a role in a group activity.

Comparison with Prior Research

The findings of this study align with previous research on non-verbal communication in mathematics learning in students with mild intellectual disabilities (Huscroft-D'Angelo et al., 2014). For example, Silviana and Hadi (2019) emphasized that visual-verbal communication skills play a vital role in mathematical problem-solving, with high-achieving students demonstrating better communication skills. This suggests that non-verbal

communication, such as visual aids (e.g., pictures or symbols), can help students with disabilities understand complex mathematical concepts more effectively. Additionally, research by Sari (2023) highlighted that weak memory and understanding of symbols are major obstacles for children with disabilities in mathematics, further supporting the importance of integrating non-verbal communication into mathematics instruction.

The study also observed how manipulatives, such as the bowls and marbles used in this research, contributed to the student's ability to perform division. This hands-on learning approach allowed students to interact directly with the learning material, clarifying their understanding of mathematical concepts. As seen in the case of Student 2, those who were more confident and communicative could use the manipulatives effectively to complete the division task. On the other hand, students like Student 3 and Student 4, who were less active, relied more on teacher instructions and showed less initiative in using the bowl and marbles, indicating the significant role that active engagement plays in learning.

Research on teaching aids in mathematics learning shows that teaching aids can significantly improve students' mathematical understanding and communication, including students with disabilities. Teaching aids reduce the abstraction level of mathematical concepts, which is often an obstacle for students with special needs. For example, research by Resqueta and Mutianingsih shows that using props in non-standard weight measurement in primary schools can improve students' math learning outcomes (Resqueta & Mutianingsih, 2022). In addition, research by Khotimah and Risan emphasized that teaching aids help students understand abstract mathematical concepts, espe-

cially in space-building materials (Khotimah & Risan, 2019).

Furthermore, research by Simarmata et al. (2022) shows that using learning media suitable for the characteristics of students with disabilities can improve their understanding of mathematical concepts. This is in line with the findings of Rokhim et al. (2023), which state that the right learning media can help students with disabilities understand difficult materials, such as science and mathematics. Thus, teaching aids serve as a learning medium and a bridge to improve mathematical communication among students with special needs so that they can more actively participate in the learning process. Using a realistic approach to learning, as proposed by Kurniati, students can more easily understand the mathematical concepts taught (Kurniati, 2022). Therefore, teaching aids in mathematics learning, especially for students with disabilities, have improved their mathematical understanding and communication.

Implications for Teaching Strategies

The study also supports the idea that hands-on learning effectively improves students' mathematical communication skills with mild intellectual disabilities. According to Widodo et al. (2021), hands-on learning, as seen in the Discovery Learning model, effectively enhances students' mathematical communication skills. This was also echoed in research by Sholihah et al. (2022), which emphasized that positive learning experiences increase students' confidence, improving their ability to communicate mathematically. Moreover, Istimuryani et al. (2023) found that inquiry-based learning, which often includes hands-on elements, helps improve mathematical communication skills.

However, it is also important to consider the potential drawbacks of hands-on

learning. Research by Siburian and Saija (2019) pointed out that some students may struggle to connect hands-on experiences with abstract mathematical concepts, which can hinder their ability to communicate mathematical ideas effectively. Similarly, Lubis and Dewi (2023) noted that while hands-on learning may increase student engagement, not all students can articulate their understanding clearly after engaging in practical activities. This is particularly true for students with mild disabilities who may face challenges linking their hands-on experiences with verbal explanations. Therefore, educators should be mindful of these challenges and ensure students are supported in relating their hands-on experiences to broader mathematical concepts (Lisnawati et al., 2024).

Implication of Research

The implication of research from the above information is related to several important aspects that can affect the learning approach of students with intellectual disabilities, especially in understanding the concept of division. Here are some of the implications:

(a) **The Role of Communication in Learning:** Verbal and non-verbal communication skills are crucial in helping students with intellectual disabilities understand mathematical concepts. Teachers should pay more attention to clear verbal instructions and support them with non-verbal cues such as pointing or directing gestures to assist students in completing division tasks.

(b) **Structured Learning Approach:** This research implies the importance of a structured approach in teaching the concept of division to students with special needs. Teachers must give instructions gradually, using visual sharing strategies

such as bowls and stars, and provide immediate corrections when students make mistakes. This can improve students' understanding and engagement in learning.

(c) **Differentiation of Learning Based on Student Needs:** Each student demonstrates different abilities in sharing and communicating. This shows that a different approach is needed for each student. Teachers can tailor each student's learning strategies by understanding the differences in numeracy, communication, and concept comprehension, making learning more inclusive and effective.

(d) **Student Confidence Enhancement:** Students who received more support, both verbally and through physical guidance, showed improvement in completing division tasks. This implies that building students' confidence through effective communication and direct support will improve their ability to complete math tasks independently in the future.

Limitation

This study has several limitations, including a small sample size of only four students with varying characteristics. This limits the generalizability of the findings, as each student exhibited different levels of understanding and responses to the concept of division. Additionally, the study was conducted in a single school with a homogeneous socioeconomic background, where the students came from economically disadvantaged families. In this context, parents were often occupied with work to meet their families' basic needs, resulting in minimal interaction between students and their parents. This lack of parental involvement likely influenced the level of support students received for their learning at home, potentially affecting their mathematical communication skills and comprehension.

The study did not explicitly measure

external factors influencing students' communication skills and mathematical understanding, such as parental involvement, access to additional learning resources, or home learning environments. The homogeneity in socioeconomic conditions and the absence of external variable measurements may have limited the interpretation of the findings. Future research should expand the sample by including students from schools with more diverse socioeconomic backgrounds. Additionally, measuring external factors such as parental engagement, time available for home study, and support from the learning environment is essential. Such an approach is expected to provide a more comprehensive understanding of the factors affecting students' mathematical communication skills and comprehension.

CONCLUSION

The conclusion of this study shows that mathematical communication skills, both verbal and non-verbal, play an important role in understanding and implementing the concept of division in students with mild intellectual disabilities. The difference in students' ability to calculate, communicate, and actively participate in learning emphasizes the need for a structured learning approach tailored to individual needs. Learning methods that utilize manipulatives, such as bowls and marbles, effectively improve students' understanding of division, although some students still need intensive guidance to associate practical experience with abstract explanations. This study also emphasizes the importance of providing verbal support and clear non-verbal cues to strengthen students' involvement in learning and encourage their confidence in completing tasks independently. With adaptive and student-based teaching

strategies, mathematics learning can become more inclusive and effective for students with mild intellectual disabilities.

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Development of Student Worksheets on Pythagorean Theorem Content Based on Creative Problem Solving to Facilitate Mathematical Reasoning Ability

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Abstract

Mathematical reasoning ability is one of the most important parts of mathematics learning. However, the facts show that students' mathematical reasoning ability is still low, especially in the context of the Pythagorean theorem. One attempt to facilitate this is using students' worksheets based on creative problem solving (CPS). This research aims to develop valid and practical student' worksheets. It refers to the 4D development model, which includes defining, designing, developing, and disseminating. The instruments used are validation and practicality questionnaire sheets. The results of the validity assessment of students' worksheets were very valid, with an average percentage of 95,07%. The results of the practicality assessment of students' worksheets were very practical, with an average rate of 89,38%. Thus, it is in accord with the valid and practical requirements, so the worksheet is usable. This research aims to make it easier for students to build knowledge independently in mathematics learning so that mathematical reasoning abilities can be facilitated.

Keywords: Creative Problem Solving; student worksheet; Teorema Pythagoras

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Abstrak

Kemampuan penalaran matematis (KPM) menjadi salah satu aspek yang terpenting dalam pembelajaran matematika, namun fakta menunjukkan KPM peserta didik masih rendah khususnya pada konten teorema Pythagoras. Salah satu upaya untuk memfasilitasi masalah tersebut dengan menggunakan Lembar kerja peserta didik (LEMBAR KERJA SISWA) berbasis Creative Problem Solving (CPS). Tujuan penelitian ini adalah mengembangkan LEMBAR KERJA SISWA yang valid dan praktis. Penelitian pengembangan ini mengacu pada model pengembangan 4D yang meliputi define, design, develop, dan disseminate. Instrumen yang digunakan adalah angket validasi dan angket praktikalitas. Hasil analisis data angket validasi diperoleh bahwa LEMBAR KERJA SISWA dikategorikan sangat valid dengan persentase rata-rata yaitu 95,07%. Hasil analisis data angket praktikalitas diperoleh bahwa LEMBAR KERJA SISWA dikategorikan sangat praktis dengan persentase rata-rata yaitu 89,38%. Maka, LEMBAR KERJA SISWA pada penelitian ini telah memenuhi syarat valid dan praktis sehingga dapat digunakan dalam kegiatan pembelajaran. Implikasi dari penelitian ini adalah untuk mempermudah peserta didik dalam membangun pengetahuan secara mandiri pada pembelajaran matematika sehingga kemampuan penalaran matematis dapat terfasilitasi.

INTRODUCTION

Mathematics learning in the Independent Curriculum aims to develop mathematical reasoning (Kemendikbudristek, 2022). Mathematical reasoning is drawing conclusions based on several statements whose truth is known (Setialesmana et al., 2021). Mathematical reasoning ability is the ability of students to formulate and conclude a strategy to solve problems (Rosidah et al., 2020). Therefore, this mathematical reasoning ability is important for students at every level of education, including junior high school (Permatasari et al., 2020). (Hidayat et al., 2018) also stated that mathematical reasoning ability is one of the abilities that can build students' thought patterns in the development of mathematics learning. This shows that mathematical reasoning ability is an important part of learning mathematics.

The facts show that mathematical reasoning ability is still considered low. Research results by Absorin & Sugiman (2018) found that some students needed help to express mathematical ideas through pictures. Of the 390 junior high school students in Indramayu Regency, only around 67 students could apply the correct reasoning steps. This shows that the mathematical reasoning abilities of grade VIII junior high school students still

need to improve. Pradana & Murtiyasa (2020) showed that students' mathematical reasoning in solving problems had yet to reach the standard.

The Pythagorean theorem is one of the materials that has problems in mathematical reasoning. The results of the study by Demircioğlu & Ilter (2022) stated that mathematical reasoning ability in the Pythagorean theorem material is still said to be low, where there are several difficulties in visualization, conceptual knowledge gaps for proof purposes, and difficulties in formal proof. Another fact shows that there are still problems in students' mathematical reasoning abilities based on research on the content of Cartesian coordinates and the Pythagorean theorem to 22 students in class VIII-E MTsS Darul Hikmah Pekanbaru. The results of measuring the mathematical reasoning abilities of class VIII-E MTsS Darul Hikmah Pekanbaru students using the mathematical reasoning ability scoring guidelines in Table 1.

Table 1. Percentage of Students' Maximum Scores for Each Indicator of Mathematical Reasoning Ability

| No | Indicators of Mathematical Reasoning Ability | N* | Percentage |
|----|---|----|------------|
| 1 | Presenting mathematical statements in writing, diagrams, and pictures | 13 | 59,1% |
| 2 | Carrying out mathematical manipulations | 6 | 27,3% |
| 3 | Arrange reasons for the truth of the | 5 | 22,7% |

| No | Indicators of Mathematical Reasoning Ability | N* | Percentage |
|----|--|----|------------|
| | solution | | |
| 4 | Concluding logically | 5 | 22,7% |

N*: number of students who can achieve the indicators

The percentage of the indicator presenting mathematical statements in writing, diagrams, and images is 59.1%, meaning that more than half of the students can correctly present statements in questions in the Cartesian plane. Other participants still need to make mistakes and need help even to present statements in questions in the Cartesian plane. Other reasoning ability indicators show that the average percentage of students who can meet these indicators is 22.6%. This indicates that most students need help to perform mathematical manipulation, compile and provide reasons for the truth of the solution, and draw logical conclusions from statements correctly.

Mathematical reasoning is the most essential ability students must have in mathematics. (Tum, 2024). However, according to Chuang et al. and Chuang et al. (2021), the facts show that students need a higher understanding of abstraction, where students often need help understanding the abstract concepts necessary to solve logical problems. Students also depend on external assistance to analyze information, and student awareness is needed to generate new ideas for effective problem-solving strategies.

An alternative learning model that can help improve mathematical reasoning is Creative Problem Solving (CPS) because students are encouraged to be able to reason faster in solving problems (Hamid et al., 2023). The CPS model is related to mathematical reasoning because, in reasoning, facts are connected to solving problems creatively. (Çoban & Tezci, 2022). Various research results also state that reasoning abilities can be effectively improved by using the CPS model

(Wasiran & Andinasari, 2019). Özaydin & Arslan (2022) also showed that applying the CPS model can improve students' mathematical reasoning. Therefore, using the CPS model is considered to facilitate mathematical reasoning abilities.

The definition of the Creative Problem Solving (CPS) model is a learning model that focuses on teaching and problem-solving skills and strengthening skills (Septian et al., 2020). The CPS model introduces, understands, and applies information and teaches to analyze and solve problems (Kartikasari et al., 2022). One of the advantages of the CPS model is that it allows students to develop their thinking skills to solve problems quickly (Fathonah et al., 2023). CPS provides challenges for students so that curiosity arises from solving issues, resulting in students being more actively involved in learning (Eladl & Polpol, 2020). CPS is based on constructivist learning theory, which states that learning is an active process carried out by students. (Thampinathan, 2022). The learning process is interactive, and students will exchange ideas related to the problems presented so that they can analyze and solve them well. (Septian et al., 2020).

There are three CPS model procedures, namely (1) Fact Finding, which involves defining the problem, collecting and analyzing related data and information; (2) Idea Finding, which is related to generating and modifying ideas about strategies for solving problems; and (3) Solution Finding, namely an evaluative process that culminates in finding the final solution (Kartikasari et al., 2022). The main phases of the creative process are (1) the imaginative phase, generating and debating new ideas that emerge to obtain ideas for solving problems, and (2) the practical phase, where ideas are evaluated and implemented (Septian et al., 2020). Therefore, the CPS stages in

mathematics learning are (1) Clarification of the problem, including ensuring that all students understand what kind of solution is required for the problem; (2) Brainstorming, students are given the freedom to express ideas or thoughts about various problem-solving strategies; (3) Evaluation and selection, each group member will evaluate the pros and cons of each opinion until deciding on a final choice; and (4) Implementation, carrying out mathematical calculations using the final choice resulting from the previous stage (Kartikasari *et al.*, 2022).

The implementation of CPS needs to be supported by learning media that can develop mathematical reasoning skills. Mathematical reasoning impacts mathematics learning outcomes; increasing mathematical reasoning will also improve learning outcomes or vice versa (Chuang *et al.*, 2021; Ramazan *et al.*, 2023). Student worksheets are a learning resource that can increase activity and learning outcomes (Munifah *et al.*, 2019). Student worksheets are sheets containing instructions for use, questions that students and materials must complete, and a summary explaining the basic competencies that must be achieved (Basuki & Wijaya, 2019). Applying student worksheets in the learning process is expected to motivate students to improve their reasoning skills. Student worksheets are learning products that facilitate students to experiment, increase activity, and achieve learning goals (Bayram *et al.*, 2003).

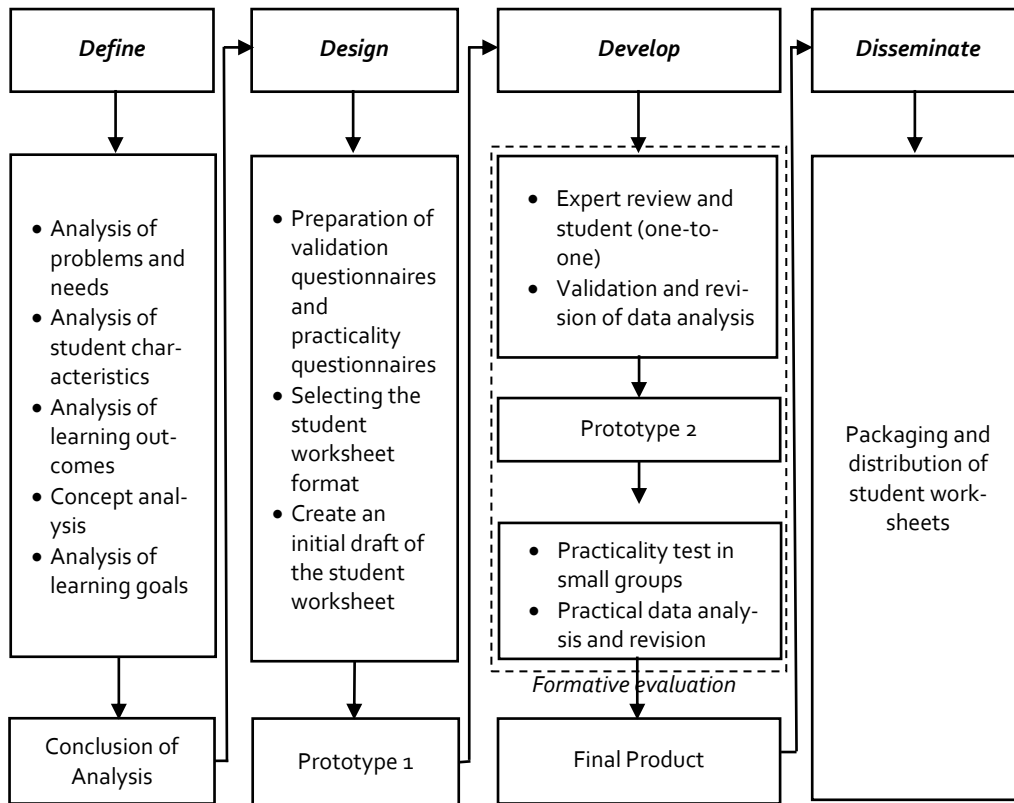
The observations and interviews

with mathematics teachers at MTsS Darul Hikmah Pekanbaru and SMPN 8 Pekanbaru showed that student worksheets still need to be improved. The worksheets only contain practice questions, so they do not facilitate students' mathematical reasoning. Student worksheets should consist of questions and activities that include instructions on completing tasks according to basic competencies and learning outcome indicators to be achieved (Yasin *et al.*, 2019). Therefore, the research focused on developing student worksheets on Pythagorean theorem content based on Creative Problem Solving (CPS) to facilitate the mathematical reasoning abilities of phase D students.

METHOD

This research is included in the research and development category, which is defined as developing a product through the planning process of conducting product validity tests. (Sugiyono, 2021). Development research aims to produce new products or refine and improve existing products. The products made in this study are student worksheets based on CPS on the content of the Pythagorean theorem for grade VIII phase-D.

The development model used in this research is the 4D development model by Thiagarajan *et al.* (1974), with stages including define, design, develop, and disseminate. Figure 1 shows the development procedure in this study.



Picture 1. The step of Development Research

Define

Activities in the define stage are problem analysis and data collection for needs analysis. Activities to analyze problems and needs, student characteristics, learning outcomes, concepts, and learning objectives are five steps in the define stage. Problems are analyzed from research and literature studies (Sugiyono, 2021). Data collection techniques at the define stage through observation, interviews, and conducting tests on students' mathematical abilities. Observations and interviews were conducted with teachers of SMPN 8 and MTsS Darul Hikmah Pekanbaru. Mathematical reasoning ability tests were conducted on MTsS Darul Hikmah Pekanbaru class VIII-E students. The results of the define stage are conclusions from the analysis activities that will be used as a basis or focus in the form of problems and solutions from this study.

Design

The design stage is the stage of designing a product that is developed according to the data obtained from the analysis results of the define stage. The design stage includes four steps, namely (1) compiling criteria through compiling a validation sheet to measure the validity of the product being developed, then compiling a practicality questionnaire sheet to measure the practicality of the product being developed; (2) format selection, namely designing learning media, selecting strategies, methods, approaches, and learning resources; (3) media selection, selecting programs that will be used to support product development; and (4) initial product design, creating an initial product or product design that will then be assessed at the developing stage. The design stage produces prototype 1 through a validation questionnaire, a practicality questionnaire, and an initial

product design. Student worksheets were created, which will be assessed later in development. Student worksheets will contain the title of the material, instructions, learning objectives, material, and practice questions. Student worksheets are arranged based on the CPS syntax, namely (1) problem clarification, (2) expressing opinions, (3) evaluation and selection, and (4) implementation (Shoimin, 2020).

Develop

The development stage is carried out by developing student worksheets from the design stage. First, the student worksheets are validated by expert validators using validation questionnaire instruments. The development stage is divided into two steps, namely Expert Appraisal and Development Testing. An expert appraisal is an activity to validate the product being developed. Developmental testing is a trial activity of a product that has been created on the actual target. During this trial, response data, reactions, or comments from the product's target users are sought. The results of the trial are used to improve the product.

Expert review is an initial activity, namely the process of one or more experts reviewing a rough version of a product or product still in design. Expert assessment of student worksheets includes three aspects, namely face validity, content validity, and construct validity. The validation results are analyzed and revised. After the student worksheet is declared valid and revised according to the suggestions given by the validator, one-to-one sessions are held. The one-to-one activity obtains input and comments from students, which will be used to revise the student worksheet. Then, a small group practicality test is carried out to assess the practicality of the student

worksheet. The practicality assessment uses a practicality questionnaire that students will fill out. This questionnaire includes four assessment aspects: ease of use, presentation, readability, and time. The results of the practicality questionnaire are analyzed, and then the student worksheet is revised. The result of this stage is the final product in the form of a valid and practical student worksheet.

Disseminate

Spreading a tested product for the use of others is known as dissemination (Sugiyono, 2021). Disseminate is handing over products to school teachers so they can be used in learning activities (Faizah *et al.*, 2023). Therefore, this stage is used for the packaging and disseminating the final student worksheet products.

The data of this study are quantitative and qualitative. The data sources in this study were obtained through several activities: (1) Observation, namely taking data through observation of the learning process carried out at SMPN 8 Pekanbaru. Then, written in the researcher's notes; (2) Validation: this data was obtained from the validation questionnaire the validator had filled out. The validation questionnaire used a scale of 4 to obtain quantitative data. It was equipped with a comment column to obtain qualitative data in the form of suggestions and input, and (3) Trial data was obtained from the results of observations of one-to-one activities and students who had filled out the practicality questionnaire in small groups with class VIII students of SMPN 8 Pekanbaru as research subjects. The one-to-one stage obtained qualitative data related to product clarity and time usage. The small group used a practicality questionnaire using a scale of 4 to obtain quantitative data. It was equipped with a comment column to obtain quali-

tative data through suggestions and input.

The data collection instrument for this study was a questionnaire. A questionnaire is a data collection instrument that provides written questions that respondents must answer. The questionnaire used in this study was a validation questionnaire filled out by the validator and a practicality questionnaire that students would fill out. Both questionnaires used a Likert scale format. The component assessment scale in the validation questionnaire for answers very appropriate was given a score of 4, appropriate was given a score of 3, inappropriate was given a score of 2, and very inappropriate was given a score of 1. The practicality questionnaire contained questions using a scale of 4 to strongly disagree, disagree, agree, and strongly agree.

Validity is measured using a validity questionnaire, which is useful for assessing product quality. (Chotimah & Festiyed, 2021). The design of student worksheet validation questionnaire was designed based on three aspects, namely (a) face validity with indicators of supporting elements of presentation, integration of student worksheets, suitability of images, and suitability of writing; (b) content validity with indicators of suitability of material with Learning Achievements, the accuracy of the material, up-to-dateness of material, encouraging student activity, and suitability of material with student thinking level; and (c) construct validity with indicators of suitability of student worksheets with CPS model and indicators of mathematical reasoning ability, attracting user attention to learn, clarity of presentation, and accuracy of language use. The design of the validation questionnaire grid was modified by Nainggolan (2022) and Akbar & Holid (2017).

Paskevicius & Irvine (2019) stated

that practicality is practical or easy to use. The practicality questionnaire was designed based on four aspects, namely (a) ease of use with indicators of ease of use assessment based on appearance, ease of implementation in the learning process, and the availability of adequate answer space to be filled in (b) presentation with indicators of clarity of problem presentation assessment, and understanding of the content on the Student Worksheet; (c) readability with indicators of clarity of text or writing so that it can be read, use of simple and understandable language, and clarity of instructions for using the student worksheet; and (d) time with indicators of efficiency of learning time assessment towards the speed of student learning. The design of the practicality questionnaire grid was modified by Pahrudin et al. (2020).

Data analysis is finding and formulating data collected systematically from observations, field notes, interviews, questionnaires, and documentation. This process includes making easy conclusions by organizing data into categories, describing them into units, synthesizing, and creating patterns. This study analyzes qualitative and quantitative data. Qualitative data analysis reduces data, which is then presented descriptively. Data reduction is the analysis process by sorting out important data that researchers need. Quantitative data analysis is obtained from validation questionnaires and practicality questionnaires.

Validity analysis is seen from the validation questionnaire filled out by the validator with the developed student worksheets considered valid if they have a validity value of more than 70%. If the validity value does not reach 70% in the study, it means that the student worksheets are declared less valid, and a validity test is carried out again by the researcher. Analysis of the practicality of

the student worksheets seen from the contents of the practicality questionnaire with the developed student worksheets is considered practical if they have a practicality value of more than 70%. If the practical quality value does not reach 70% in the study, then the student worksheets are revised, and the researcher carries out a practicality test again.

RESULTS AND DISCUSSION

Results

This study produces student worksheets on Pythagorean theorem content based on CPS to facilitate valid and practical mathematical reasoning skills in the D-phase through the following stages.

Define

The define stage analyzes problems and needs, student characteristics, learning outcomes and concepts, and learning objectives. Based on the analysis activities, conclusions were obtained consisting of several things, including (1) Low mathematical reasoning skills in mathematics learning, especially in the content of the Pythagorean theorem for grade VIII phase-D; (2) low use of student worksheets and even no CPS-based student worksheets have been found that can measure students' reasoning abilities in mathematics learning; (3) In terms of student characteristics, students need LEMBAR KERJA SISWA so that they are more active and enthusiastic in the learning process; (4) student worksheets for the Pythagorean theorem content are based on learning outcomes that refer to BSKAP No. 033/H/KR/2022 and the Pancasila student profile in accordance with the independent curriculum; and (5) The content of the Pythagorean theorem refers to student mathematics books and teacher guide mathematics books for

grade VIII phase-D of the 2022 independent curriculum consisting of 7 learning objectives with a total of 14 lesson hours. This analysis becomes the basis or foundation for carrying out the next stage.

The result of the define stage is the Learning Objective Flow of the Pythagorean theorem content. Learning Objective Flow design is based on learning outcomes. Learning Outcomes (CP) are knowledge, attitudes, and skills arranged into a single continuous process to build complete competencies from a subject. Learning outcomes are competencies students must possess at each phase (Badan Standar Kurikulum dan Asesmen Pendidikan, 2022). The Learning Objective Flow design results can be seen in Table 2.

Table 2. Learning Objective Flow Pythagorean Theorem Content

| | |
|--------------------------|--|
| Unit Learning Objectives | Students can demonstrate the truth of the Pythagorean theorem and use it to solve problems (including the distance between two points on the Cartesian coordinate plane). |
| Learning Objectives Flow | G.1 Proving the Pythagorean theorem G.2 Calculating the hypotenuse and other sides of a right triangle using the Pythagorean theorem G.3 Determining Pythagorean triples G.4 Determining the length of a triangle's side using the Pythagorean theorem G.5 Comparing the sides of a special right triangle G.6 Solving problems in everyday life related to the Pythagorean theorem G.7 Applying the Pythagorean theorem to find the distance between two points on the Cartesian coordinate plane t Cartesian). |
| Element Content | Geometry Pythagorean Theorem |
| Total lesson hours | 14 |

| | |
|-------------------------------|---|
| Profile of Pancasila Students | Critical, creative, and collaborative thinking |
| Glossary | Hypotenuse, Pythagoras, right triangle, acute triangle, obtuse triangle, theorem, Pythagorean theorem |

The content arrangement in this study refers to the independent curriculum, namely that listed in the BSKAP Kemendikbudristek 2022 learning guide. The student worksheets developed are based on the Learning Objective Flow in Table 1. The content of the Pythagorean theorem is divided into seven topics, namely proving the Pythagorean theorem, finding the length of the hypotenuse, Pythagorean triples, the length of the sides of a triangle with the Pythagorean theorem, Special triangles, applying the Pythagorean theorem, and the distance between two points on the Cartesian coordinate plane.

Design

The design stage consists of designing validation and practicality instruments that will be used to measure the validity and practicality of student worksheets. Researchers also select a format adjusted to the CPS model and the media chosen, namely printed media in the form of student worksheets. The final activity at this stage is to create an initial design of the student worksheet consisting of 7 sub-topics of the Pythagorean theorem on geometric elements referring to BSKAP No.033/H/KR/2022. The results of this stage are prototype 1 in the form of a validation questionnaire, a practicality questionnaire, and an initial design of the CPS-based Pythagorean theorem student worksheet.

The product of developing student worksheets based on CPS on the Pythagorean theorem content to facilitate reasoning skills in the form of a book with a

structure of cover, foreword, table of contents, learning flow and objectives, concept maps, and student worksheets. The learning flow and objectives page contains the identity, unit learning objectives, learning objectives, rationale for compiling the learning flow and objectives, and the learning objective flow. The components of the student worksheet consist of the cover, the student worksheet's contents, the student worksheet, and the end of the student worksheet. The student worksheet's cover consists of the student worksheet's title, the material's title, supporting images, student identity, learning objectives, and instructions for completing the student worksheet. The learning objectives for each student worksheet are made based on the learning material for each meeting.

The content of the student worksheet is designed according to the CPS model, which consists of 4 stages: problem clarification, opinion expression, evaluation and selection, and implementation. The initial part of the student worksheet presents a contextual problem related to students, or students can imagine that. Furthermore, at the problem clarification stage, a column is given known and asked, and several questions that can trigger students' understanding of the problem given. Students' answers at the problem clarification stage indicate that they have understood the problem presented and the plan for solving it. The second stage is opinion expression. At this stage, students are asked to fill in what opinions or strategies will be used by students to solve the problem. The third stage is evaluation and selection; each group discusses the right strategy to solve the problem and works on the activities presented on the student worksheet that can help find the strategy. The fourth stage is implementation. At this

Table 3. Results of Student Worksheet Validation Analysis

| Validator Rating Average | Aspects of Assessment | | | Validation Average |
|-----------------------------|-----------------------|------------------|--------------------|-----------------------|
| | Face Validity | Content Validity | Construct Validity | |
| student worksheet -1 | 96,35% | 93,06% | 96,21% | 95,21% |
| student worksheet -2 | 95,83% | 92,36% | 96,21% | 94,80% |
| student worksheet -3 | 95,83% | 92,36% | 95,45% | 94,55% |
| student worksheet -4 | 95,83% | 93,75% | 96,21% | 95,26% |
| student worksheet -5 | 96,88% | 93,06% | 94,70% | 94,88% |
| student worksheet -6 | 96,35% | 93,75% | 97,73% | 95,94% |
| student worksheet -7 | 95,31% | 93,06% | 96,21% | 94,86% |
| average | 96,05% | 93,06% | 96,10% | 95,07% |
| Category | Very Valid | Very Valid | Very Valid | Very Valid |

stage, students solve the problem until it is finished using the previously agreed strategy.

The final part of the student worksheet contains the activities "Conclusion" and "Let's Practice!". Students are asked to make conclusions from the material in the student worksheet activities. Furthermore, in the Let's Practice section, 1 or 2 questions regarding the related material are given. The questions are contextual, meaning familiar or close to the students' daily lives.

Develop

Prototype 1, produced from the design stage, was discussed again with the supervising lecturer. The student worksheets that the supervising lecturer had approved were then validated by three validators: two lecturer validators and one practitioner validator. The validators in this study were: (1) L1, validation was carried out face-to-face. She is a lecturer from Mathematics Education, University of Riau; (2) L2, validation was carried out via mail review. She is a lecturer from Mathematics Education, University of PGRI Jombang; and (3) L3, validation was carried out face-to-face. She is a driving teacher for the mathematics subject from SMPN 4 Pekanbaru. Validation activities help obtain assessments and suggestions for improving student worksheets. The results of the validation of student worksheets by the validators can

be seen in Table 3. The average percentage for all student worksheets in the aspects of face validity, content validity, and construct validity was obtained at 96.05%, 93.06%, and 96.10%, respectively, with a very valid category.

The average percentage of validation results of the three validators for the entire student worksheet obtained based on Table 3 is 95.07% with a very valid category. The average percentage of validation values for each student worksheet from the three validators obtained is 95.21% for student worksheet-1 with a very valid category, 94.80% for student worksheet-2 with a very valid category, 94.55% for student worksheet-3 with a very valid category, 95.26% for student worksheet-4 with a very valid category, 94.88% for student worksheet-5 with a very valid category, 95.94% for student worksheet-6 with a very valid category, and 94.86% for student worksheet-7 with a very valid category. The validator concluded that the student worksheet was worth being tested with revisions according to suggestions. The average validation results by the three validators for the entire student worksheet were 95.07% with a very valid category, meaning that the CPS-based student worksheet with Pythagorean theorem content to facilitate the mathematical reasoning abilities of phase-D students has met the validity aspects used.

The student worksheets have undergone considerable improvements af-

ter being revised according to the suggestions given by the validator. The resulting student worksheets included problems based on the indicators of mathematical reasoning ability. Contextual images accompany the student worksheets to describe problems in real situations. The student worksheets also include supporting sources of information that can foster students' reasoning abilities. The sentences on the student worksheets have been written clearly and are easy to understand. The end of the student worksheet contains evaluation questions to measure the achievement of students' mathematical reasoning abilities, one of which is contextual.

The result of the overall revision based on the suggestions and input given is a valid student worksheet. The student worksheet has been declared valid qualitatively and quantitatively. The student worksheet is qualitatively declared valid based on the results of comments and suggestions from the validator. The student worksheet has been quantitatively declared valid based on the questionnaire results with the "very valid" category.

The student worksheets were then given to three students at SMPN 8 Pekanbaru to carry out one-to-one activities. The purpose of the one-to-one activity was to determine the readability of the student worksheets and the reactions of students who had heterogeneous ability levels when working on the student worksheets, which were used to improve the student worksheets. The researcher provided an introduction before the students worked on the worksheets. The researcher provided instructions on reading and understanding each activity in

the student worksheets to the maximum. The researcher also allowed students to ask questions if they needed help understanding the instructions on the student worksheets.

The results of the one-to-one activity were that students could complete the student worksheets according to the specified time, which was 35 minutes for one student worksheet. The time recorded included the questioning activity. It shows that student worksheets can be used in learning activities at school with a minimum of two lesson hours for one student worksheet. At the end of the one-to-one activity, the researcher discussed with students the student worksheets developed to obtain suggestions and comments from students, namely the presence of incorrect use of words, difficult-to-understand problem sentences, and typing errors on the student worksheets. Based on these suggestions and comments, the researcher improved the student worksheets. The results of the improvements to the student worksheets from the one-to-one stage are called prototype 2.

The next stage is a small group where student worksheets are given to 15 students of class VIII SMPN 8 Pekanbaru for seven meetings. Each student is given a worksheet to work on and discuss in groups. The researcher briefly explains the instructions for completing the student worksheets that will be worked on. The researcher accompanies and directs students if they need help completing the student worksheets. The researcher also observes the activities and responses of students when working on the student worksheets.

Table 4. Results of the Student Practicality Questionnaire in Small Group Activities

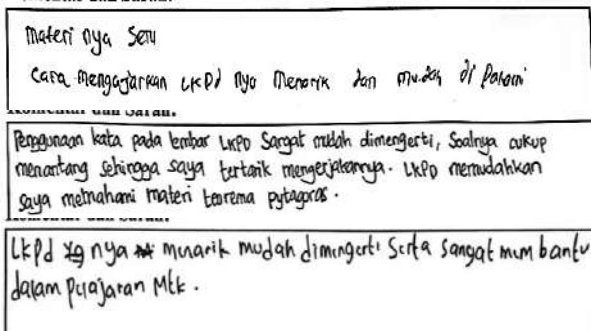
| Assessment Aspects | Average Value of Student Practicality Questionnaire for Student Worksheets (%) | | | | | | | Average |
|----------------------|--|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Ease of Use | 92,78 | 95,00 | 90,83 | 92,78 | 90,83 | 90,83 | 89,17 | 91,75 |
| Presentation | 91,67 | 90,67 | 88,67 | 87,67 | 87,67 | 85,00 | 87,00 | 88,34 |
| Readability | 88,33 | 89,00 | 89,33 | 90,00 | 90,67 | 91,33 | 88,33 | 89,57 |
| Time | 88,33 | 89,17 | 87,50 | 87,50 | 86,67 | 87,50 | 88,33 | 87,86 |
| Average Practicality | 90,28 | 90,96 | 89,08 | 89,49 | 88,96 | 88,67 | 88,21 | 89,38 |
| Category | Very Practical | Very Practical | Very Practical | Very Practical | Very Practical | Very Practical | Very Practical | Very Practical |

Based on the researcher's observations, some students had doubts at the beginning of the learning process and asked questions when completing the student worksheet. After students understood the work procedure and discussed it with their group members, students became more active in completing the activities on the student worksheet. The researcher distributed a practicality questionnaire to students after completing the student worksheet. The results of this practicality questionnaire assessed the student worksheet's practicality. The results of the practicality analysis are shown in Table 4.

Based on Table 4, it is obtained that the average percentage of the practicality questionnaire from student worksheet-1, student worksheet-2, student worksheet-3, student worksheet-4, student worksheet-5, student worksheet-6, and student worksheet-7 are respectively 90.28%, 90.96%, 89.08%, 89.49%, 88.96%, 88.67%, and 88.21% with a very practical category. Regarding ease of use, the average percentage of the practicality questionnaire for student worksheet-1 to student worksheet-7 is 91.75%, meaning that the student worksheet is easy to use or has been categorized as practical. The readability aspect obtained an average percentage of 89.57%, meaning that the writing of sentences is clear so that it can be understood. The presentation aspect obtained an average per-

centage of 88.34%, meaning that the presentation of the material has been presented well so that it is categorized as very practical. The time aspect obtained the lowest average percentage value of 87.86%, which means that some respondents still feel that more time is needed to complete student worksheets. The results of the practicality questionnaire on student worksheets on the Pythagorean theorem content based on CPS for students in phase D show that student worksheets meet the very practical category with an average practicality score of 89.38%.

In the comments and suggestions section of the practicality questionnaire, students stated that the developed student worksheets could help them understand the content of the Pythagorean theorem. Students stated that the student worksheets had a display design and color composition that was quite attractive, so they were enthusiastic about working on the student worksheets. Some of the comments and suggestions from students can be seen in Figure 2. Small group activities such as student worksheets experienced slight improvement. The results of small group activities are called final products in the form of valid and practical student worksheets.



Translated

The material is exciting

The way to teach student worksheets is interesting and easy to understand.

The use of words on student worksheets is very easy to understand, the questions are challenging so I am interested in doing them. Student worksheets make it easier for me to understand the Pythagorean theorem material.

Student worksheets are interesting, easy to understand and very helpful in math lessons.

Figure 2. Comments and Suggestions on the Practicality Questionnaire

Disseminate

The dissemination stage consists of 2 activities: product packaging and product distribution to product users to schools by submitting student worksheets to the school, namely SMPN 8 Pekanbaru. The following is a cover display of the packaging of student worksheets for the Pythagorean Theorem content based on CPS, which can facilitate the mathematical reasoning abilities of phase-D students.



Figure 3 Final Product Cover

Discussion

This research and development study used the stages in the 4-D development model. In the define stage, the researcher reviewed the analysis of problems and learning needs, student characteristics, curriculum, and materials. This analysis shows that learning in schools uses the Merdeka curriculum, and students need student worksheets that can facilitate reasoning skills by the CPS model, thus helping students review and solve problems faced by using the information obtained. The results at this stage are analytical conclusions used to proceed to the design stage.

Researchers compile validation and practicality questionnaires to measure validity and practicality in the design stage. Researchers also select student worksheet formats that are adjusted to the CPS model. The final activity at this stage is to create an initial design of student worksheets consisting of 7 sub-topics of the Pythagorean Theorem on geometry elements that refer to the Merdeka curriculum. The results at this stage are called prototype 1.

Prototype 1 was discussed with the supervisor and continued to the next development stage. This stage is divided into two activities, namely (1) expert appraisal consisting of expert review and one-to-one activities and (2) development testing; the activities carried out in this study were small groups. The results of the expert appraisal and development testing stages were, respectively, prototype two and the final product. The results of the expert review and one-to-one activities were in the form of student worksheets declared valid. The average percentage results of the overall validation questionnaire from the three validators were 95.07% with a very valid category. A student worksheet's validity is

based on the opinion that student worksheets can be considered valid if they have a validity value of more than 70% (Akbar & Holid, 2017).

Regarding face validity, the student worksheets obtained an average validity percentage of 96.05% with a very valid category. Namely, the student worksheets already have a good appearance based on the integration and suitability of the presentation of supporting elements, images, and writing. In line with Gustiningsi *et al.* (2022) & Widodo *et al.* (2023), student worksheets are attractive to motivate students to follow the learning process. The average percentage of validity obtained by the student worksheet in the content validity aspect is 93.06% with a very valid category, meaning that the material or content of the student worksheet has been included and adjusted to the learning achievements and learning objectives to be achieved, relevant to the 8th-grade junior high school mathematics textbook. (Tohir *et al.*, 2022). Regarding construct validity, the student worksheet obtained an average validity percentage of 96.10% with a very valid category, meaning that the student worksheet was by the CPS syntax according to Shoimin (2020) and indicators of mathematical reasoning ability according to Linola (2017). Therefore, the CPS-based student worksheet on the Pythagorean theorem content has fulfilled the validity aspect. Nur Hasanah *et al.* (2023) also stated that the student worksheets were valid and could then be tested.

The validated student worksheets were given to 3 students to be done one to one. The revision of the student worksheets at this stage was only in the form of improvements to the use of words, more straightforward problem sentences, and typos on the student worksheets. The result of revising the student work-

sheets was prototype 2, which was valid and could be continued to small group activities.

Small group activities were conducted to assess the practicality of student worksheets based on the practicality questionnaire data analysis results. The average percentage of practicality results for all student worksheets is 89.38% in the very practical category, meaning that student worksheets based on CPS with Pythagorean theorem content facilitate mathematical reasoning abilities that meet the practicality aspect.

The average percentage of the practicality questionnaire obtained on the ease of use aspect of student worksheet-1 to student worksheet-7 is 91.75%, with a very practical category. The aspect is assessed based on ease of use in appearance so that students can easily use student worksheets when studying. Pahrudin *et al.* (2020) stated that one of the advantages of using student worksheets is clarity and ease of use during implementation in the learning process. In terms of presentation, the average percentage of practicality obtained is 88.34%, which is a very practical category. The material, learning activity flow, and problems have been presented well. The readability aspect obtained an average percentage of practicality of 89.57%, which is a very practical category, which means that the writing of sentences is clear and can be easily understood. Fitriani *et al.* (2023) stated that student worksheets are practical with clear and easy-to-understand writing, language, and sentences. The time aspect obtained the lowest average percentage of 87.86%, including the very practical category. Several respondents felt the need for more time to complete student worksheets due to limited time availability during the study. Fitriyani *et al.* (2023) stated that students only completed

some questions on the student worksheet due to the short implementation time. Students also commented on the developed student worksheet, saying that it was interesting and easy to understand, and the writing on the student worksheet was clearly legible. The results of the small group activities were analyzed and revised to produce a final product in the form of a valid and practical student worksheet.

Each activity on the student worksheet is adjusted to the CPS syntax and the reasoning ability indicators to be achieved. This includes (1) presentation of contextual problems so that students feel familiar or close to them; (2) students are asked to understand the problem so that they can present mathematical statements independently; (3) students are allowed to express their opinions and discuss with groups so that they can carry out mathematical manipulation and provide truth to the solution; and (4) solve problems based on the information obtained until finally making a logical conclusion. This study is in line with the statement that student worksheets are a learning resource that can increase student activity and learning outcomes, which impact students' mathematical reasoning abilities. (Pahrudin et al., 2020).

The changes in students' mathematical reasoning abilities are supported by students' involvement in active learning, in accordance with students' comments, which stated that they were more enthusiastic and interested in participating in the learning process. This is in line with Kartikasari et al. (2022) & Septian et al. (2020), who stated that CPS also resulted in students being more active in learning. According to Vygotsky, the quality of learning depends on the quality of student interaction in the learning process (Mota-Valtierra et al., 2019). This is

in accordance with the theory of constructivism, which has the principle of an active process in learning so that students can construct their knowledge well (Thampinathan, 2022). According to Sulistyowati & Sugiman (2014), learning with CPS is related to the theory of constructivism because the exchange of ideas carried out by students in learning activities with CPS results in students being able to solve the problems given so that they obtain good learning outcomes. Good learning outcomes can also have an impact on students' mathematical reasoning abilities (Chuang et al., 2021; Ramazan et al., 2023).

CPS has an important role in influencing mathematical reasoning ability in this study. This is in accordance with several research results which state that the application of the CPS model has been proven to improve mathematical reasoning ability effectively (Hamid et al., 2023). This shows empirical evidence that CPS-based student worksheets can have a positive impact on students' reasoning ability.

The advantages of this study are that the student worksheets have an attractive appearance, and the problems given are familiar to students. The product consists of seven student worksheets, meaning it covers the entire scope of the Pythagorean theorem content. However, the disadvantage of this study is that it has yet to measure the effectiveness of the student worksheets. In addition, the items in the validation and practicality questionnaires have yet to show the CPS model and indicators of mathematical reasoning ability specifically.

Implication of the Research

The results of this study have implications for mathematics learning, especially on the Pythagorean theorem material,

namely that teachers can use student worksheets as a reference for learning media in the teaching and learning process according to the current Merdeka curriculum. Research on developing CPS-based student worksheets on the Pythagorean theorem material that can facilitate mathematical reasoning skills. Therefore, this study can be used as a source of information as well as a reference for other studies that want to develop student worksheets using different materials or abilities. The development of CPS-based Pythagorean theorem content student worksheets has met the requirements for validity and practicality but has yet to reach the point of measuring effectiveness. This allows for further research to be carried out on an effectiveness test so that trials can be carried out on a wider scale.

Limitation

This research employs the 4D method, encompassing distinct stages where the researcher undertakes specific activities. While precision is emphasized at each stage, achieving absolute perfection is not the primary focus. Further testing is required to assess the effectiveness of the resulting product across a broader range of subjects.

CONCLUSION

This study produced a product in the form of a student worksheet on the Pythagorean theorem content that was adjusted to CPS so that mathematical reasoning abilities were facilitated. The student worksheet produced has been validated and tested to obtain a very valid and practical category. Therefore, the student worksheet on the Pythagorean theorem content based on CPS to facilitate the mathematical reasoning abilities

of phase-D students has met the requirements of being valid and practical.

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Development of a Local Instruction Theory for Trigonometric Ratios

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Abstract

Some students find trigonometric ratios challenging. Research on the application of Local Instruction Theory (LIT) in trigonometry is limited, particularly in secondary school understanding of trigonometric ratios. This study aims to develop an LIT for trigonometric ratios using Realistic Mathematics Education (RME). The researcher designed a learning pathway to help students grasp the fundamental concepts of trigonometric ratios. The study employs a research design methodology, developing a Hypothetical Learning Trajectory (HLT) to improve students' understanding. The development of LIT for Trigonometric Ratios follows three stages: initial design, teaching experiments, and retrospective analysis. Students demonstrated the ability to understand trigonometric ratios through the learning process. The findings suggest that the use of LIT-based instructional materials, incorporating RME principles, significantly enhances students' conceptual understanding of trigonometric ratios in high school.

Keywords: Local Instruction Theory; Hypothetical Learning Trajectory; Trigonometric Ratios; RME

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Abstrak

Beberapa siswa menganggap materi perbandingan trigonometri cukup sulit. Penelitian tentang penerapan Local Instruction Theory (LIT) dalam pembelajaran trigonometri masih sangat terbatas, khususnya terkait dengan pemahaman rasio trigonometri di sekolah menengah. Penelitian ini bertujuan untuk mengembangkan Local Instruction Theory (LIT) perbandingan trigonometri dengan menggunakan Realistic Mathematic Education (RME). Dalam upaya membantu siswa membangun konsep dasar pada materi perbandingan trigonometri, peneliti mengembangkan alur LIT dengan menemukan jalur pembelajaran yang efektif. Pencapaian tujuan penelitian menggunakan desain penelitian. Serangkaian kegiatan mengembangkan Hypothetical Learning Trajectory (HLT) sehingga siswa sekolah menengah atas (SMA) memiliki pemahaman yang lebih baik tentang perbandingan trigonometri. Pengembangan Local Instruction Theory untuk Perbandingan Trigonometri meliputi tiga tahap yaitu mengembangkan desain awal, melakukan percobaan pengajaran, dan melaksanakan analisis retrospektif. Siswa mampu membangun pemahaman tentang perbandingan trigonometri selama proses pembelajaran berlangsung. Berdasarkan analisis kualitatif eksperimen pengajaran, penelitian ini berimplikasi pada penguatan Local Instruction Theory (LIT) perbandingan trigonometri dan pengembangan bahan ajar berbasis RME.

INTRODUCTION

The topic of trigonometric ratios is fundamental in the application of advanced applied sciences and pure sciences. Various fields of study require the use of trigonometry as an essential basis for applying their concepts. For example, the utilization of trigonometric ratios supports the proof of Kepler's first law (Simha, 2021). The importance of understanding trigonometric ratios lies in its role as fundamental knowledge for comprehending pre-calculus and calculus, such as algebra, geometry, and the ability to create graphs (Weber, 2005). Trigonometric comparison is utilized in calculating the width or height of various shapes, such as a bridge, household tools, and bicycles (Urrutia et al., 2019). Indeed, students see the topic of trigonometric ratios as challenging (Blackett & Tall, 1991; Weber, 2005; Yiğit Koyunkaya, 2016; Karthikeyan, 2017; Urrutia et al., 2019; Nordlander, 2022). During the initial stage of learning, students encounter difficulties in connecting triangle images to numerical relationships, as well as problems in manipulating the involved symbols (Blackett & Tall, 1991), and many students are unable to overcome these difficulties. While studying right triangles, students struggled to grasp the concept of trigonometric functions, such as sine, cosine, and tangent, which are defined as ratios (Weber, 2005a, 2008). According to Yiğit (2016), students exhibit a lack of flexibility when solving trigonometric comparison problems (Yiğit Koyunkaya, 2016). Students expressed that trigonometry was a subject that was highly

stimulating and conceptual in comparison to other areas of mathematics (Karthikeyan, 2017). According to Sandip's research, trigonometry is a challenging subject that is disconnected from everyday life (Urrutia et al., 2019). Typically, students struggle to distinguish the front side, side view, and slanted side of a right triangle even though this distinction greatly aids their comprehension of trigonometric ratios. The topic of trigonometric comparison is considered abstract for students (Karthikeyan, 2017).

From the preliminary study and literature review conducted by the researcher on textbooks, instructional videos, analysis of students' learning difficulties, and curriculum analysis, several aspects have caught the researcher's attention. One of these aspects is the emergence of real-world contexts in trigonometry materials in textbooks. Various examples have begun to present contextual situations, but teachers still need to learn how students might construct formal concepts from the presented contextual case. Batanero dan Diaz (2012) argue that the existing textbooks and curriculum documents need to sufficiently support learning, as the presented concepts are narrow in scope (Batanero & Díaz, 2012).

The typical pattern of learning that occurs in the delivery of contextual mathematics is the initial introduction and presentation of example problems, followed by the completion of practice exercises using general formulas. The typical pattern of learning still represents the teaching culture in carrying out the

learning process. According to Weber (2005), mathematics learning in schools still follows the conventional sequence of explanation, example provision, and problem-solving practice. The learning process via direct application of general formulas can prevent students from developing their mathematical concepts independently (Weber, 2005b). Their thinking patterns need to be trained, resulting in a lack of familiarity with how these formulas are derived.

The application of real-life models to formal mathematical concepts has yet to be documented in supporting learning materials. The teacher must possess the ability to elucidate the models generated by students during the learning process, which can subsequently facilitate the comprehension of formal mathematics. Turmudi (2018) states that students should have a strong desire in the learning process to independently discover concepts, if teachers provide facilities, teaching materials, and learning resources (Turmudi, 2012).

According to Sandip's research, trigonometry is a challenging subject that is disconnected from everyday life (Adhikari & Subedi, 2021; Asomah et al., 2022; Dhungana et al., 2023). To bridge this gap, Realistic Mathematics Education serves as an alternative to teaching trigonometric ratios. Realistic Mathematics Education (RME) is a teaching and learning method in math education that follows the philosophy of Hans Freudenthal, who sees math as a human endeavor. (Freudenthal, 1973; Gravemeijer & Terwel, 2000; Treffers, 1987; Van den Heuvel-Panhuizen & Drijvers, 2020).

Realistic Mathematics Education is characterized by students experiencing a concrete learning process that is aligned with real-life situations and contextualized according to their everyday lives (Yunita et al., 2018). Students undergo an

informal process of constructing their understanding based on what they see, observe, and comprehend about their surrounding environment, be it at home, school, or wherever they learn (Meika, 2018).

The three primary ideas of Realistic Mathematics Education are guided reinvention and progressive mathematizing, didactical phenomenology, and self-developed models. (Gravemeijer, 1994). During the teaching and learning process, these three principles are elaborated into five characteristics of RME, namely: 1) Building and solidifying; 2) degree and frameworks; 3) contemplation and specific task; 4) societal environment and communication; and 5) organizing and intertwining (Gravemeijer, 1994; Lange, 1987). The significance of the Realistic Mathematics Education approach resides in its ability to empower students to develop concepts through interactive teaching and learning processes. The teachers have a crucial role in enabling students to explore concepts using both administrative and motivational methods (Meika, 2018).

The mistakes made by previous students should not be repeated in the following years. The provision of instructional materials is an effective solution for improving the situation and facilitating recovery. The focus of learning will be further narrowed down if the instructional materials used are appropriate. In this teaching material, steps are needed that can facilitate students' learning paths. According to Gravemeijer, to improve mathematics education, it is necessary to implement an instructional design that facilitates learning and enables students to progress from their current level of thinking to a more sophisticated level of mathematical thinking (Gravemeijer, 2004).

Local Instruction Theory (LIT) is a comprehensive theory that includes both

the process of acquiring knowledge on a specific topic and the methods used to facilitate that learning (Liljekvist et al., 2017). LIT was developed in the 1990s as part of an ongoing research initiative into the adaptation of instructional strategies within mathematics education. LIT has been primarily applied in various educational contexts, particularly in mathematics classrooms across several countries, including the Netherlands, where the theory was initially developed. It is also relevant to the Indonesian educational context, as demonstrated in our study. Gravemeijer states that Local Instruction Theory is an exact theory that can assist students in developing mathematical thinking on a particular topic or material through detailed and gradual instructional medium (Gravemeijer, 2004). Researchers will develop a systematic learning path, also known as a learning trajectory, within the process of teaching and learning. This design is the one Gravemeijer mentioned.

LIT is used to describe the appropriate learning route or learning activities. LIT not only offers how learning takes place but also facilitates a range of specific learning activities that may work. The existence of LIT provides a basis for teachers to consider adaptations that may be needed in implementing new approaches. In addition, LIT offers a framework in which teachers can develop hypotheses about learning trajectories. LIT is tailored to the specific circumstances of the particular class and teacher. Teachers need to build HLT (Hypothetical Learning Trajectories) that are suitable for their own situations while using LIT as a foundational reference (Gravemeijer, 2004).

Understanding and applying (LIT) is essential for teachers as it serves as a bridge between theoretical frameworks and practical classroom instruction. LIT provides a structured approach to

creating Hypothetical Learning Trajectories (HLTs), which help teachers anticipate and guide students' learning processes while adapting to their evolving needs. This process enables educators to align instructional activities with students' thinking and learning paths, ensuring a deeper and more meaningful understanding of mathematical concepts.

For example, guided reinvention and mathematization are central aspects of LIT. These strategies empower students to develop informal problem-solving methods that can be refined into formal mathematical reasoning, fostering their ability to connect classroom learning with real-world applications. Teachers' proficiency in LIT also facilitates the identification and addressing of misconceptions, promoting continuous conceptual development (Gravemeijer & Doorman, 1999; Van Den Heuvel-Panhuizen, 2002).

Furthermore, professional development programs incorporating LIT principles have demonstrated that teachers equipped with this knowledge are better prepared to design effective and flexible instructional sequences tailored to their students' needs. These programs emphasize the importance of using LIT to design activities that encourage reasoning, discussion, and reflection, which are key for fostering higher-order thinking skills (Gravemeijer, 2004).

The implementation of Local Instruction Theory (LIT) by teachers is often done through a contextual activity-based approach to help students understand mathematical concepts. For example, in teaching the concept of combination with the RME approach, teachers can use demonstrations such as handshakes or color mixing to connect abstract concepts to real-world situations, which have been shown to be effective in improving student understanding. However, teachers face challenges in adjusting learning

designs to meet the needs of heterogeneous students, especially in aligning the Hypothetical Learning Trajectory (HLT) with classroom dynamics. Teachers have difficulty in designing learning activities that are contextual enough and engage students at a deeper level of engagement (Meika et al., 2019).

Based on preliminary research conducted by the researcher, no teacher at this school has ever implemented *Local Instruction Theory* (LIT) in teaching, particularly in the topic of trigonometric ratios. The lack of training and understanding of how to apply LIT to the curriculum is the main reason why teachers have not utilized this approach. As Gravemeijer notes, although LIT has proven effective in certain educational contexts, its implementation requires a deep understanding of its principles and methods. Teachers often face challenges when trying to apply innovative teaching strategies like LIT due to limited opportunities for professional development and curriculum constraints (Gravemeijer & Doorman, 1999). Furthermore, adapting LIT to specific topics, such as trigonometric ratios, can be a barrier if teachers do not have the necessary tools and support. Therefore, the lack of LIT implementation in this school makes it a relevant area for further research development.

HLT is developed for each learning activity and plays a crucial role in designing student learning tasks. The implementation of teaching is closely tied to the learning trajectory, which includes a planned sequence of learning content and the conceptual map students navigate during the learning process (Prahmana, 2016). In the subsequent phase, a Local Instruction Theory (LIT) for trigonometric ratios is developed.

Based on the explanation above, there is a need for the development and design of instructional materials that can

minimize students' difficulties in developing thinking processes through Realistic Mathematics Education (RME) to construct an understanding of trigonometry content. These instructional materials are expected to be obtained through the design of LIT. This approach aims to address several challenges faced by students and to foster the development of their mathematical thinking, particularly in understanding trigonometric ratios through Realistic Mathematics Education.

According to the given definition, it is crucial to create and design instructional resources that can reduce students' challenges in developing cognitive processes through Realistic Mathematics Education to build comprehension of trigonometric concepts. The desired teaching materials are obtained through the LIT design. The LIT design is used to address the difficulties experienced by students and to enhance their mathematical thinking process, particularly their understanding of trigonometric ratios through Realistic Mathematics Education.

METHOD

In the book *Educational Design Research* by Koeno Gravemeijer, the conclusion highlights the importance of design research in bridging theory and practice within education. Design research allows for the development of innovative and contextually relevant learning tools that can be adapted and tested in real classroom environments. One of its key strengths is the ability to generate new theories based on real-world learning experiences, emphasizing the interaction between students, teachers, and learning materials (Nieveen et al., 2006).

Moreover, design research provides a framework for continuous reflection and improvement of teaching practices and learning strategies through iterative

cycles of development, implementation, and evaluation. This ensures that the educational solutions developed are both effective and adaptable, ultimately enhancing the overall quality of education. Through this process, design research contributes to creating educational solutions that are both grounded in theory and practical in diverse educational settings.

A design research method based on Gravemeijer's approach is the research methodology used. This research method is focused on local instruction theory, or LIT, which was developed by researchers in collaboration with teachers to achieve better learning quality (Gravemeijer & van Eerde, 2009). A study paradigm known as "design research" tries to create a series of tasks and comprehend the workings of the learning process. This study aims to develop and construct a Local Instruction Theory (LIT) on the subject of trigonometric ratios, with a focus on Realistic Mathematics Education (RME).

Gravemeijer proposes a research design for the development of local instruction theory. The research design consists of three phases: 1) preliminary design (developing initial design), 2) teaching experiment (doing teaching experiment), and 3) retrospective analysis (performing retrospective analysis) (Gravemeijer, 2004). Preliminary design is the outcome of an initial learning plan aimed at implementing ideas about the development of instructional materials for LIT (Meika, 2018). This design is expected to support students in the construction of mathematical thinking from an informal form to a formal one. The construction of mathematical thinking is achieved through a guided reinvention process facilitated by mathematizing. Mathematizing refers to several ways of managing learning activities to demonstrate mathematical characteristics, such as generality, certainty,

accuracy, and agility (Loc & Hao, 2016). The purpose of the teaching experiment is to evaluate the effectiveness of the instructional materials for LIT. Retrospective analysis is employed to examine the complete dataset of the teaching experiment outcomes.

HLT is applied in every learning activity and has a crucial role in designing learning activities for students. The execution of learning is indissociable from the learning trajectory, encompassing a deliberate progression of learning materials and idea maps that students traverse during the learning process (Prahmana, 2016). Next, in the subsequent stage, the trigonometric ratios LIT is produced (see Figure 1).

The research implementation is carried out in two stages, with each stage referring to the steps of design research (Gravemeijer, 2004) namely: The three main stages of the project include 1) formulating the initial concept, 2) executing the educational experiment, and 3) carrying out a retrospective study. During the teaching experiment phase, this study involved 30 tenth-grade students from SMAN 7 Bandung. The selection of Grade 10 at SMAN 7 Bandung was based on the rationale that this class had already engaged with the national curriculum currently implemented in Indonesia, where trigonometric ratios constitute a key topic. Additionally, the school was chosen because it represents senior high schools that consistently adhere to the implementation of the national curriculum. This selection provided an opportunity to explore the application of trigonometric ratios within a context relevant to Indonesia's existing educational framework.

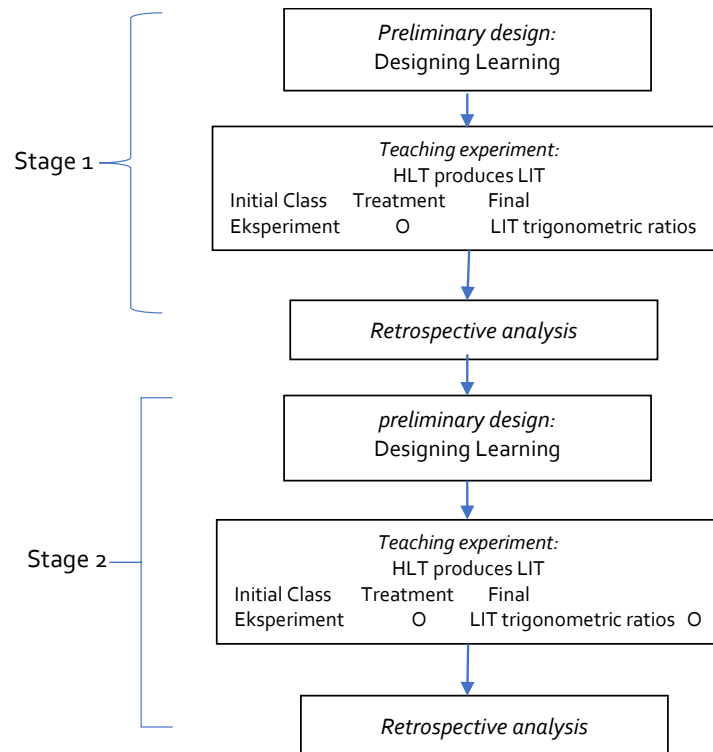


Figure 1. Research Design

An analysis was conducted on the activities performed in the initial phase, and subsequently, recommendations were given to enhance the activities in the second phase. The findings from the data analysis of the second phase provide the final recommendations of this research.

Preliminary findings indicate that no teachers at this school have implemented Local Instruction Theory (LIT) in their teaching practices, particularly in the context of trigonometric ratios. The primary reasons for this include limited training opportunities and a lack of understanding regarding LIT's application in the classroom. Gravemeijer (1999) highlights that while LIT has proven effective in various educational contexts, its implementation requires a comprehensive understanding of its principles and methodologies. Teachers often face challenges in adopting innovative teaching strategies like LIT due to insufficient professional development opportunities and curriculum constraints. Additionally, adapting LIT to specific topics, such as trigonometric ratios,

poses further challenges if educators lack adequate tools and support. Consequently, the absence of LIT's application for this topic at the school underscores the relevance and potential for further research and development in this area.

Data for this research was collected using multiple methods to gather comprehensive insights. First, written data were obtained from test results, tasks such as UBA-LIT and LKPD, and observation sheets during the teaching experiments. Second, documentation in the form of video recordings and photographs were used to observe classroom activities, student interactions, and the process of mathematization. Additionally, direct observation was conducted by the researcher, who also acted as the teacher, noting student responses during the learning process. Interviews with selected students were carried out to gather deeper insights into their experiences with UBA-LIT and LKPD. The data were analyzed qualitatively by comparing the observations and video recordings with

the initial teaching design (HLT). Internal validity was ensured through data triangulation from various sources, while reliability was strengthened by testing the instruments and conducting cross-interpretation with experts. The conclusions were drawn from the retrospective analysis of the collected data, explaining how students grasped the concept of trigonometric ratios within the learning process using LIT.

RESULTS AND DISCUSSION

Results

The research is carried out in three stages: 1) formulating the fundamental design, 2) executing the teaching experiment, and 3) implementing the retrospective analysis.

Elaborating on the Initial Design (preliminary design)

During this phase, the researcher assembles the educational materials and finalizes the instructional content. To meet the study aims, various actions are conducted, including (1) identifying the research subjects based on their diverse cognitive abilities. The researchers selected students from class X of SMAN 7 as appropriate research subjects; (2) examining and analyzing the curriculum to identify the compatibility of trigonometric comparison material with the curriculum currently being used in the school; (3) analyzing trigonometric comparison material to obtain an overview that "the achievement of Phase E-learning based on the derived geometry domain becomes the learning objective," in accordance with the research objectives. Next, the researcher developed a teaching material design in the form of a descriptive outline of trigonometric comparisons, also known as "Local Instruction Theory

Descriptive Teaching Material (UBA-LIT)". The Realistic Mathematics Education (RME) technique enhances the learning process by employing diverse learning materials, including teaching modules and research tools. The study instrument is designed to incorporate the specific attributes of Realistic Mathematics Education (RME) and the curriculum used by the school. Additionally, the researchers analyze and assess the learning assistance tools. The result of the evaluation is referred to as the prototype. In the next stage, the research conducts an expert review, in which four experts validate the prototype based on its structure, content, and language.

Once the expert review procedure is finished, students who have been given trigonometric comparison information are tested on the prototype to get data on the readability and comprehension of the instructional material. The researchers engage in communication with the students during the testing process to anticipate any corrections or feedback regarding the instructional materials being tested by the students. The students write their input or suggestions on the prepared sheet. Students provide support for the discovery of formal concepts related to UBA-LIT through their comments. The researchers made improvements to the UBA-LIT after receiving feedback. After conducting expert validity testing and gathering comments from students, it was ultimately determined that the prototype design of the instructional material product generated by the researcher is valid at this level. The updated iteration of the prototype is referred to as the second prototype. Following that, the second prototype underwent testing in teaching experiment 1, including a total of 30 students from SMAN 7 Kota Bandung.

From a design research standpoint, the primary objective of the initial design is to develop a Local Instruction Theory (LIT) that can be visually portrayed as a portrayal of the process of acquiring and

improving knowledge through teaching experiments (Gravemeijer & Cobb, 2006). During the preliminary study, the researcher designed the learning process activities based on a literature review. This set of educational exercises covers the beliefs held by students while they are building knowledge and the methods that will be used, which will be presented as an initial challenge, including advanced thinking skills. The contents of HLT are subject to change. The activities in HLT can be adapted and customized based on the circumstances and parameters of the ongoing educational experiment. HLT has a curriculum that students will adhere to when studying trigonometric ratios. The HLT curriculum comprises learning objectives, activity descriptions, and student thought conjectures that occur during the learning process. During the teaching experiment, HLT functions as a reference for teachers and researchers to determine the teaching emphasis, observations, and interviews. Moreover, HLT functions as a point of reference for the examination or analysis of a dataset in the context of a teaching experiment. Hypothetical Learning Trajectory (HLT) used in the teaching experiment is displayed in Table 1 (see appendix A).

Teaching Experiment

The primary objective of a teaching experiment is to systematically evaluate and enhance original ideas regarding Local Instruction Theory (LIT) while also striving to gain a more profound comprehension of the underlying mechanisms and functioning of LIT (Gravemeijer & Cobb, 2006).

Activity 1

The teacher requested three students to perform a demonstration using the

provided tables/chairs and ropes.

The teacher requested one of the students to fasten the rope to the base of the table or chair provided. A student holds the end of the neat rope and moves back 1 meter from the base of the table/chair. After that, the student who is holding the end of the rapia rope shifts his grip to the end of the head. Other students are asked to draw sketches of the shapes that are occurring. The other students observed the demonstration requested by the teacher, depicted the requested sketch, and identified the positions of the angles, front side, side view, and oblique side of the formed triangle sketch. All students strive to comprehend the right-angled triangle sketch and identify the positions of angles, front side, side view, and hypotenuse on the sketch. The teacher provides a comprehensive understanding through the following activities (See Appendix B, Figure 2)

Activity 2

The teacher instructs the class to define the trigonometric ratios ($\sin \theta$, $\cos \theta$, and $\tan \theta$) with a demonstration involving the height of a shadow. This activity guides students in formally discovering the concept of trigonometric comparisons. The students were able to perform this activity proficiently after acquiring the idea of identifying angles and sides in the previous activity. The presented issues are contextual and aligned with the student's level of understanding. The LIT design is structured from the simplest to the most complex in order to provide a general solution. In this activity, the teacher instructs the students to face away from the light source so that a shadow appears in front of the standing students. The results of the student's practice are represented in the form of an image or sketch of a right-angled triangle. This sketch

facilitates students in identifying the positions of angles, front side, side view, and inclined side of a right triangle based on the predetermined angle. Creating a sketch of a right triangle and determining angles helps students mathematize vertically and find formal solutions to define trigonometric ratios.

Figure 3 illustrates various outcomes of students' process variations in discovering formal mathematics from the concept of trigonometric ratios. The students' work begins with a demonstration of a contextual problem, allowing them to find solutions using various methods based on their prior knowledge. During the learning process, students are guided to discover formal mathematics, which is a process of mathematization based on

the presented problems.

Activity 3

Activity 3 begins with the teacher presenting problems based on everyday life situations. Everyday scenarios were employed to enable students to apply the notion of trigonometric ratios in practical circumstances. After the activity is finished, the teacher conducts a test as a final evaluation. One of the trigonometric comparison problems presented is as follows:

"Refer to the following image of a bed. What are the geometric shapes that occur between the stairs, bed, and floor? Sketch a model. (1) Does the shape formed constitute a right triangle? If so, mark one corner with a right

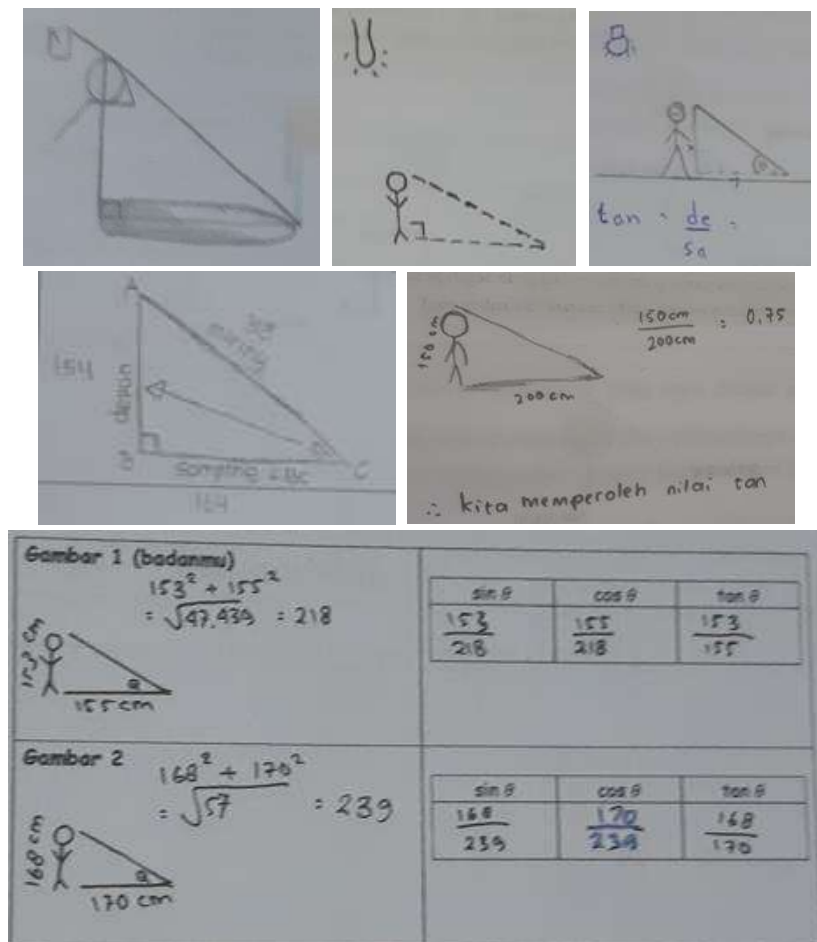


Figure 3. The vertical mathematical process of students in finding formal solutions to trigonometric ratios

angle. (2) If the angle between the stairs and the floor is unknown, and the distance from the bed to the stairs is 10 cm. Place the obtained data into the image. Subsequently, calculate the distance from the floor to the end of the staircase, which forms a right-angled triangle, using the tangent ratio. ($\tan 37^\circ = 0,75$)"



Figure 4. Image of a bed as a model for the use of trigonometric ratios

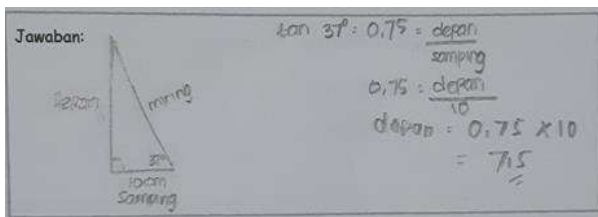


Figure 5. One of the student's responses was to solve the story problem

Figure 5 is an example of a student's response using the concept of trigonometric ratios to solve a word problem. The student solves the problem using the formal solution of trigonometric ratios that was previously constructed.

Retrospective Analysis

Researchers employ Hypothetical Learning Trajectory (HLT) as a first guide and reference when assessing a dataset during the data analysis stage of a teaching experiment. The HLT created is compared to the classroom learning process. The analysis includes descriptions of anticipated occurrences during the learning

process and examples of behaviors that will occur among students. The conclusions drawn from the analysis will answer the research questions. A good design is not the main objective of the study but rather the reason for the study's success, which is the main objective (Gravemeijer & Cobb, 2006).

The many activities carried out during the learning process are represented in the flowchart of LIT before the learning process on the topic of trigonometric ratios. The flowchart is presented in Figure 6 (See Appendix C). The image shows the differences in stages or steps during the learning process. The difference is evident in the red-colored box. Before the learning process begins, the design aims to facilitate activities, experiments, observations, group discussions, and presentations as processes that run parallel. Students will go through these stages simultaneously.

Meanwhile, after the learning process takes place, a revision of the initial design is made. The stage of differentiation involves an initial discussion process with students prior to the demonstration (See Appendix D, Figure 7). This stage provides students with an introduction to understand the concept of trigonometric ratios in relation to the prior knowledge they have already constructed. This stage is considered crucial because linking it to the previously acquired knowledge is necessary for students to comprehend the fundamental concepts of trigonometric ratios.

The next difference is in the "responding" stage, which students go through after conducting a demonstration and before the "observing" stage. The act of "responding" is the first step for students to participate actively in the learning process. The students will provide their responses or feedback to the demonstration presented. Their

knowledge will guide and stimulate the students to continue the learning process via the "observing" stage.

Before the learning process begins, the steps "activity/experiment," "observe," "group discussion," and "presentation" have the same level of suitability. There is no text provided. However, the post-learning phases in these four things exhibit distinct variations. The "responding" stage initiates the steps of learning. Next, the process begins with the "observation" stage, followed by the "group discussion" step, and concludes with the "presentation" step. The students go through the four steps of the learning process in different stages.

The appropriate use of the LIT framework, as shown in Figure 7 (See Appendix D), allows students to construct an understanding of the concept of trigonometric ratios through everyday problems. They can identify trigonometric ratios and solve real-life issues accordingly, because of analyzing the HLT and conducting teaching experiments. Based on the results of the student's work using the LIT design for trigonometric comparison, the number of students capable of completing the learning activities is determined. The students are becoming accustomed to the learning process, which involves determining mathematics formally based on pre-established models. The utilization of Pythagorean triples, the Pythagorean theorem, models (diagrams), and measuring tools can aid in achieving vertical mathematization. The students may effectively solve common problems by utilizing trigonometric ratios.

Some students found the Local Instruction Theory (LIT) approach challenging as it shifted their understanding from merely applying formulas to understanding the deeper concepts. For example, one student expressed initial difficulty with LIT's emphasis on understanding the

relationships between concepts rather than just following procedural steps. However, after grasping the underlying logic, the student felt satisfied with being able to understand the reasoning behind trigonometric ratios, rather than just memorizing formulas.

On the other hand, some students struggled to adapt to this new teaching design, especially those who were accustomed to more traditional, structured methods. A few students felt overwhelmed by the responsibility of independent learning and actively solving problems. This feedback suggests that while LIT can provide a deeper and more engaging learning experience, its effectiveness depends heavily on how well students are supported in transitioning to this new method.

Additionally, student feedback highlighted the benefits of the collaborative learning aspect of LIT. Students appreciated the group discussions and the opportunity to explore different approaches to problem-solving, which provided a more shared learning experience. However, some also criticized the method, feeling that they lacked the foundational knowledge to fully engage in the collaborative or reflective aspects of LIT, emphasizing the need for careful planning when implementing this method. These student responses offer valuable insights for refining the design and application of LIT in teaching.

The findings indicate that some students lack the prerequisite knowledge they should have acquired, which is influenced by factors such as mental unpreparedness, teacher didactics, and inadequate teaching materials (Kurniasih et al., 2020; Puspita et al., 2023). In particular, the emphasis on rote memorization of formulas, such as trigonometric ratios, without a geometric explanation, leads to a lack of motivation and understanding among

students (Andika et al., 2017; Urrutia et al., 2019). Teacher-centered methods that rely solely on memorization often result in short-term retention of knowledge (Orhun, 2002). To overcome this, teachers need a comprehensive understanding of trigonometry to connect various concepts, enhancing students' learning (Andiani et al., 2020, 2024; Rittle-Johnson & Schneider, 2014). Additionally, incorporating real-life contexts into lessons, such as through models and diagrams, makes learning more relevant and aids in the long-term retention of knowledge (Dhunganana et al., 2023). The use of Local Instruction Theory (LIT) and Realistic Mathematics Education (RME) approaches has been shown to improve students' ability to construct their understanding of trigonometric ratios, as evidenced by their improved learning outcomes.

Discussion

The introduction of Local Instruction Theory (LIT) in this study revealed significant improvements in students' conceptual understanding of trigonometric ratios. Unlike traditional teacher-centered approaches, LIT facilitated deeper connections between abstract mathematical concepts and real-life applications. This was evident in the students' increased ability to relate geometric properties to trigonometric functions.

During the teaching experiment, students exhibited greater engagement with the material, particularly when real-life problems were introduced. Many students showed improved motivation and understanding, especially those who had struggled with rote memorization in previous lessons. Their ability to visualize trigonometric ratios in practical contexts, such as through diagramming angles and distances in real-world scenarios, was significantly enhanced.

Previous studies on Local Instruction Theory have largely focused on its implementation in general mathematical contexts, but this study fills a gap by specifically applying LIT to the teaching of trigonometric ratios. By incorporating real-world contexts and geometrical reasoning, this research extends the application of LIT to improve both conceptual understanding and long-term retention in mathematics education.

Before the intervention, students struggled with memorizing trigonometric formulas and showed limited understanding of their geometric foundations. After the intervention, students were able to connect these formulas with real-world contexts, as evidenced by their improved problem-solving abilities and retention rates.

Implication of Research

The design of this Local Instruction Theory (LIT) for trigonometric ratios incorporates the syntax of the Realistic Mathematics Education (RME) approach. The foundation of this LIT is a conjecture based on the learning trajectory using RME. Consequently, the designed learning trajectory needs to be further developed to align with the specific content objectives. Researchers intending to implement a learning trajectory are advised to master various instructional strategies or approaches for designing problems. By mastering problem design, a wide array of solutions both formal and informal can be found. Additionally, exploring variations in students' experiences, influenced by factors such as prior knowledge, learning styles, or socio-economic backgrounds, could provide alternative perspectives when applying LIT.

Limitation

This study was conducted in two phases, each of which aligns with the steps outlined in design research (Gravemeijer, 2004), namely: 1) developing the preliminary design, 2) conducting the teaching experiment, and 3) performing retrospective analysis. There are two reasons for selecting only two phases in this research. First, the researcher's time and resources were limited. Second, the material in question is only implemented once a year. To address the limitations of time and resources, the researcher recommends extending the duration of the teaching experiments and incorporating digital resources. These approaches would enhance the efficiency and effectiveness of both time and resource utilization in the study. The extended timeframe allows for more comprehensive data collection, while digital resources provide flexible, accessible learning tools that can alleviate constraints related to physical materials (Means et al., 2014). Furthermore, leveraging technology enables more dynamic and scalable teaching practices, supporting diverse learning needs (Çelik & Baturay, 2024).

CONCLUSION

The outcome of the learning trajectory in this study is a Comparative Trigonometry LIT developed through the Realistic Mathematics Education (RME) approach. This theory encompasses several steps that students must go through in constructing their knowledge related to trigonometric comparisons. These steps nonetheless adhere to the syntax of the Realistic Mathematics Education (RME) approach.

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Appendix A of article entitled Development of A Local Instruction Theory for Trigonometric Ratios

Table 1. HLT illustration for learning the concept of trigonometry comparisons

| Activity | Learning Objectives | Activity Description | Conjecture |
|---|---|---|--|
| Students Demonstrate the activity of identifying by body height. | The students are able to identify the front, side, and diagonal positions by referring to specific angles of a right-angled triangle. | The teacher instructed three students to engage in a practical exercise involving the formation of a right-angled triangle using a table base, a measuring tape, and their height. Each group carefully observes the demonstration and discusses the position of the corner, front, side, and slant. | Some students may be able to illustrate a sketch of a right triangle from the demonstration activity. Some students may quickly recognize the positions of the corner, front side, side side, and hypotenuse. |
| Shows high shadow intensity activity | The students can articulate the trigonometric ratios ($\sin \theta$, $\cos \theta$, and $\tan \theta$) by employing the notion of ratios within a right triangle. | The teacher instructs the students to face away from the light until a shadow appears in front of the standing student. The sketch formed is a right-angled triangle. Students can determine the front side, side view, and diagonal side of a right triangle sketch based on the determining angle. Students will be <i>guided in rediscovering the concept</i> of trigonometric ratios. | <ul style="list-style-type: none"> - Some students may use tables as a tool to solve problems. - Certain students may employ finger manipulation methods to solve difficulties. - Some students may utilize measuring instruments to solve problems. - Some students may use the number parity method to solve problems. - Certain students may possess the ability to represent this activity in a visual manner. They initiated the construction of a model and engaged in horizontal and vertical mathematization to uncover the notion of trigonometric ratios through the shown examples. - Some students may be able to relate the demonstration process to the concept of trigonometric ratios. |
| Problem-Solving | Students can solve real-life problems related to right triangles using trigonometric ratios | Students use trigonometric ratios to solve real-life problems by performing calculations. | <ul style="list-style-type: none"> - Certain students possess the ability to perceive the relationship between sine and cosine values in mathematical calculations and are capable of streamlining the calculation process. - Some students may be able to remember or repeat knowledge they have previously acquired to solve problems. - Some students may use tables, finger methods, odd-even tricks, or measuring tools to solve problems. - Some students may directly apply trigonometric ratio concepts. |

Appendix B of article entitled Development of A Local Instruction Theory for Trigonometric Ratios

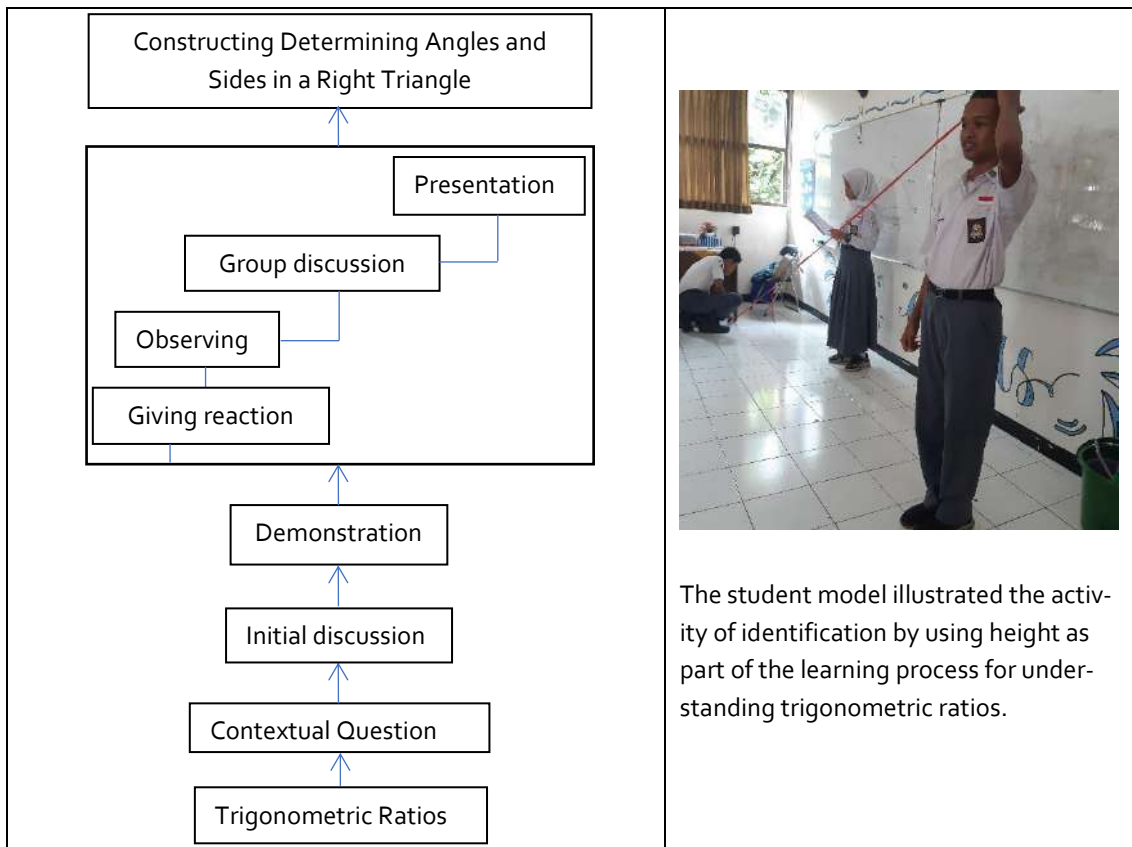


Figure 2. Demonstration of the flow of LIT and height in learning comparative trigonometry

Appendix C of article entitled Development of A Local Instruction Theory for Trigonometric Ratios

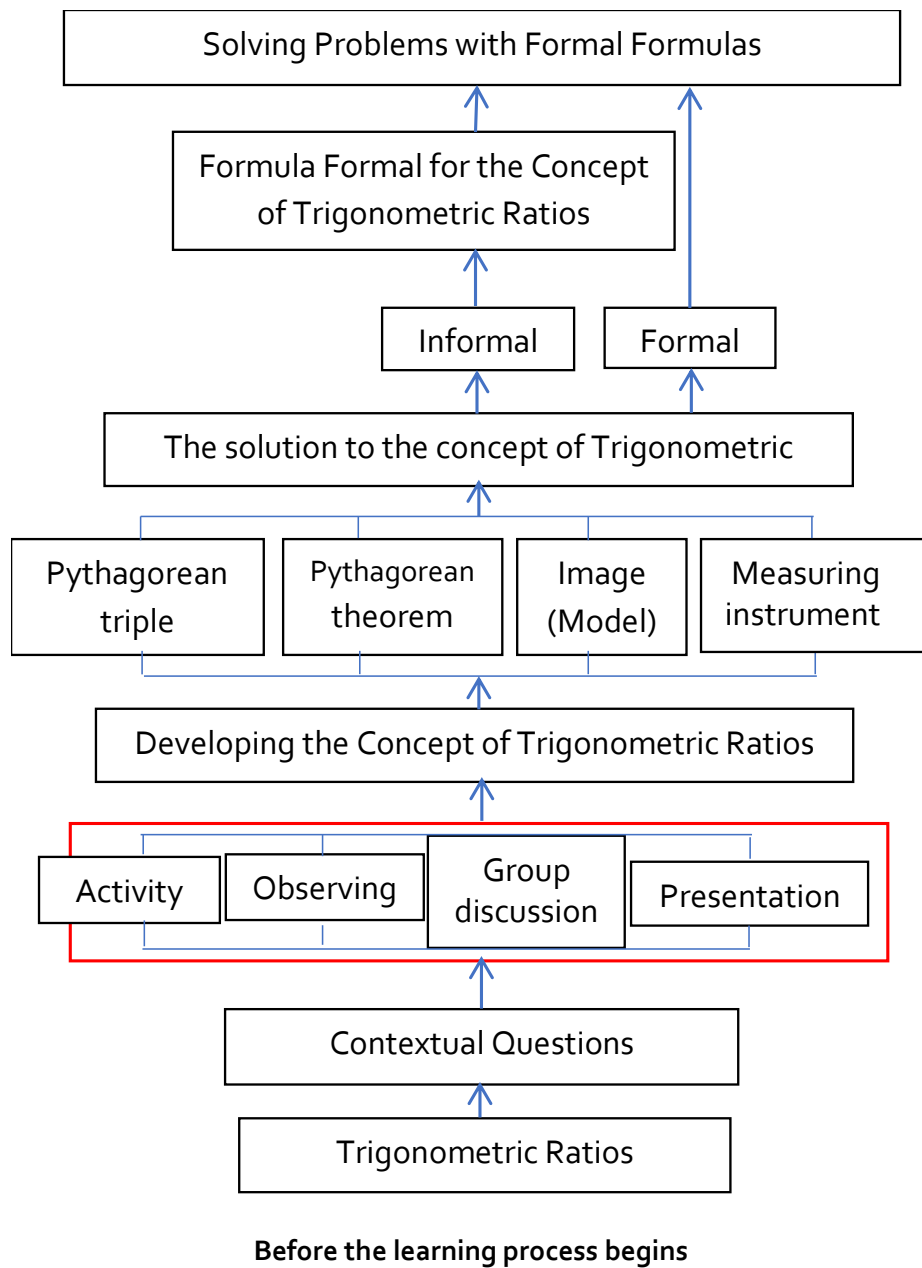


Figure 6. Flowchart of LIT on the topic of Trigonometric Ratios before the lesson

Appendix D of article entitled Development of A Local Instruction Theory for Trigonometric Ratios

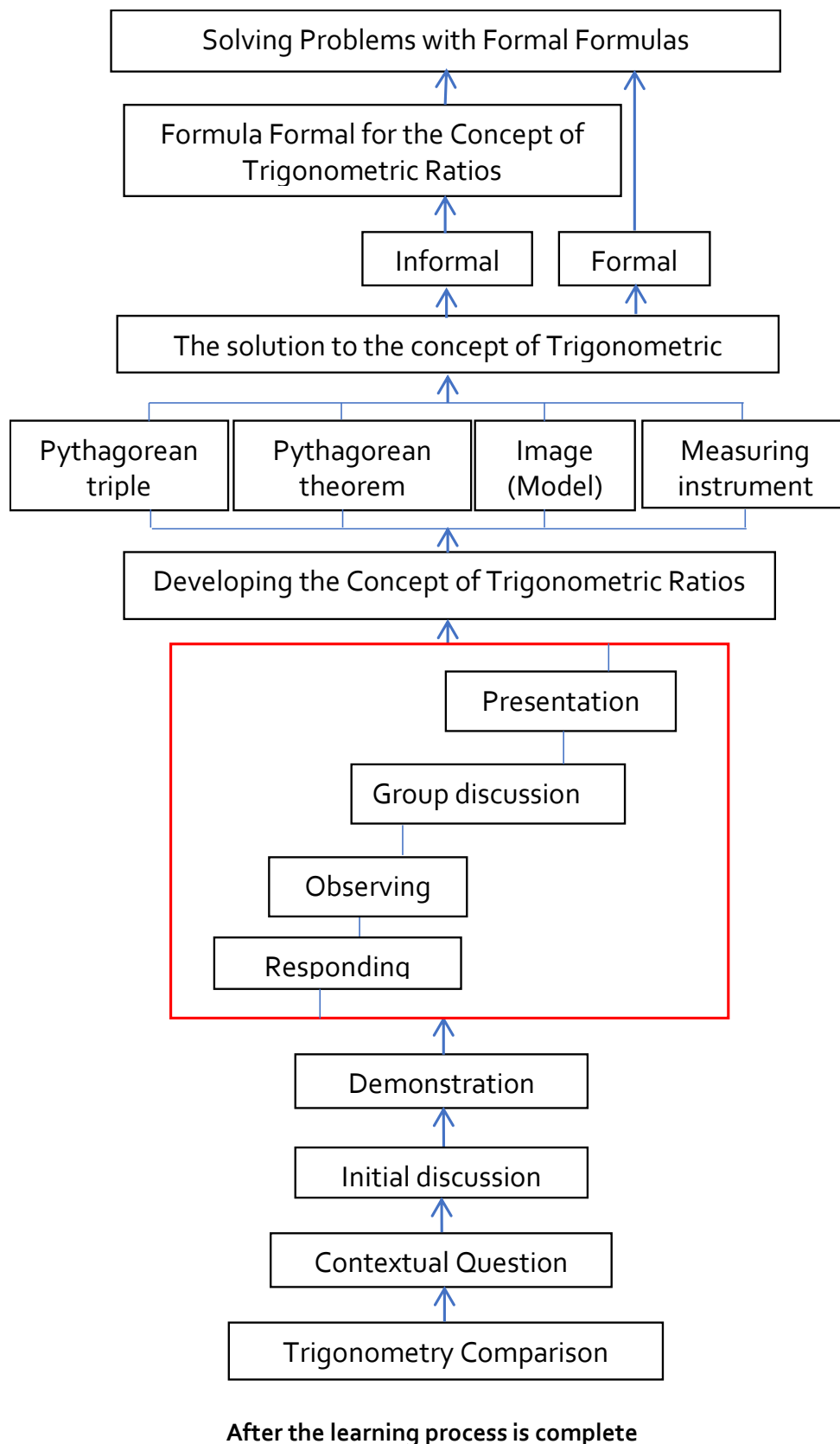


Figure 7. Flowchart of LIT on the topic of Trigonometric Ratios after the lesson



The Role and Evaluation of ChatGPT as a Virtual Tutor in Improving Students' Creative and Critical Abilities Reviewed from Probing-Prompting Abilities

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Abstract

This study reveals the potential of ChatGPT in supporting students' mathematics learning. However, the study's results also show challenges in utilising ChatGPT, such as inconsistent answer quality and potential student dependence on technology. This indicates the need for a more holistic approach to integrating ChatGPT into the learning process. This study aimed to analyse ChatGPT's ability to answer quantitative knowledge and mathematical reasoning questions, assess students' prompting abilities with ChatGPT, evaluate the use of ChatGPT, and measure the extent to which students' mathematical, creative and critical abilities have increased. This study uses an Embedded Design type of Mixed Method approach. The population in this study were all high school students who took the Tridaya Tutoring Program 2024/2025. The sampling technique used was purposive sampling, and the sample selected was all 20 students from class XII of Tridaya Tutoring High School. The research instruments used were written tests, namely multiple-choice questions and documentation studies of screenshots of ChatGPT answer results. The study results showed that the t value for measuring creative and critical abilities was 6.691 and 7.151. It was found that there was a significant difference between the test scores obtained before and after the treatment. This shows that the instructions given to students can improve their test scores. ChatGPT can help students in learning as a virtual tutor. However, it should also be noted that not all questions can be answered. Some even have different answers. This makes students dissatisfied with the results obtained. This is where students are trained in critical thinking why this can happen. In addition, the student's prompting technique for ChatGPT is also considered. There is a need for creativity in prompting so students can further explore the answers from ChatGPT. Although they can answer any question, guidance from the teacher and independent verification are needed regarding the answers given by ChatGPT so that the desired answer is by expectations.

Keywords: ChatGPT; Creative; Critical; Probing-Prompting; Virtual Tutor

Information of Article

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Abstrak

Penelitian ini mengungkap potensi ChatGPT dalam mendukung pembelajaran matematika siswa. Namun, hasil penelitian juga menunjukkan tantangan dalam memanfaatkan ChatGPT, seperti kualitas jawaban yang tidak konsisten dan potensi ketergantungan siswa pada teknologi. Hal ini menunjukkan perlunya pendekatan yang lebih holistik untuk mengintegrasikan ChatGPT ke dalam proses pembelajaran. Penelitian ini bertujuan untuk menganalisis kemampuan ChatGPT dalam menjawab pertanyaan pengetahuan kuantitatif dan penalaran matematika, menilai kemampuan prompting siswa dengan ChatGPT, mengevaluasi penggunaan ChatGPT, dan mengukur sejauh mana kemampuan matematika, kreatif, dan kritis siswa meningkat. Penelitian ini menggunakan pendekatan Mixed Method tipe Embedded Design. Populasi dalam penelitian ini adalah seluruh siswa SMA yang mengikuti Program Bimbingan Belajar Tridaya 2024/2025. Teknik pengambilan sampel yang digunakan adalah purposive sampling, dan sampel yang dipilih adalah seluruh siswa kelas XII SMA Bimbingan Belajar Tridaya yang berjumlah 20 orang. Instrumen penelitian yang digunakan adalah tes tertulis, yaitu soal pilihan ganda dan studi dokumentasi berupa tangkapan layar hasil jawaban ChatGPT. Hasil penelitian menunjukkan bahwa nilai t untuk mengukur kemampuan kreatif dan kritis adalah 6,691 dan 7,151. Ditemukan bahwa terdapat perbedaan yang signifikan antara nilai tes yang diperoleh sebelum dan sesudah perlakuan. Hal ini menunjukkan bahwa petunjuk yang diberikan kepada siswa dapat meningkatkan nilai tes mereka. ChatGPT dapat membantu siswa dalam belajar sebagai tutor virtual. Namun, perlu diperhatikan juga bahwa tidak semua soal dapat dijawab. Bahkan ada yang jawabannya berbeda-beda. Hal ini membuat siswa tidak puas dengan hasil yang diperoleh. Di sinilah siswa dilatih untuk berpikir kritis tentang mengapa hal tersebut dapat terjadi. Selain itu, teknik prompting siswa untuk ChatGPT juga diperhatikan. Perlu adanya kreativitas dalam prompting agar siswa dapat lebih mengeksplorasi jawaban dari ChatGPT. Meskipun dapat menjawab soal apa saja, diperlukan arahan dari guru dan verifikasi mandiri terkait jawaban yang diberikan ChatGPT agar jawaban yang diinginkan sesuai dengan harapan.

INTRODUCTION

The Scholastic Assessment Test (SAT) is part of the Test-Based National Selection (SNBT) for entering State Universities, which has the purpose of measuring the cognitive abilities of prospective students (KEMENRISTEK-DIKTI, 2018). One of the materials tested is Quantitative Knowledge and Mathematical Reasoning (QKMR) (Disnawati et al., 2022). The question type of SNBT is Higher Order Thinking Skills (HOTS). HOTS refers to a person's ability to think critically, analytically, evaluatively, and creatively in solving problems (Bai et al., 2023). This ability involves more than just remembering information but also analysing information, evaluating arguments, and creating new ideas (R. P. Yaniawati, 2013). The absence of special training at school results in students looking for several learning alternatives outside of school. One of them is to register with the Tutoring Institute (Fahmi et al., 2020). The method used in tutoring is lecture. Along with the times, this is not enough to support students' learning.

They find it challenging to work on their problems independently because of the limited interaction between students and tutors. Therefore, students are directed to technology that can become virtual tutors, one of which is artificial intelligence or Artificial Intelligence (AI) (Ding et al., 2023).

AI is a simulation of the intelligence possessed by humans that is modelled into machines and programmed to think like humans. AI has positioned itself at the forefront of research fields ranging from medicine and robotics to education. The application of AI in education has had a significant impact, as evidenced by the improvement of the efficiency of the educational process, the promotion of global learning, the personalisation of learning, the creation of more innovative content and the optimisation of education management in terms of effectiveness and efficiency. The application of AI in education has also become more popular and has received much news in recent years. One of the applications of AI in the world of education is using *ChatGPT* (Zein &

Gunawan, 2022; Montenegro-Rueda et al., 2023; Vong & Kaewurai, 2017; Mohamed et al., 2022; Asad & Ajaz, 2024).

ChatGPT is a recently developed conversational chatbot created by OpenAI, which can make it easier for instructors to apply AI in the teaching and learning process (To, 2023; Lo, 2023). *ChatGPT* can be a valuable educational resource for improving writing skills, as it can generate text, summarise information, and elaborate to save time and improve the quality of work (Setiawan & Luthiyani, 2023; Atlas, 2023). *ChatGPT* can also help students develop research skills by providing information and resources regarding specific topics, suggesting aspects that have not yet been discovered, and introducing them to new research topics, allowing them to understand better and evaluate the topic. (Rahman & Watanobe, 2023; Kasneci et al., 2023). Learning through *ChatGPT* requires tutors to manage good learning and provide learning assistance to students. In this context, tutors provide learning facilities or means to help students with learning difficulties. This means that tutors are facilitators and solutions to students' learning problems. In this context, tutors are divided into two different roles. First, a tutor who provides learning facilities or means and helps students learn. Second, *ChatGPT* is a virtual tutor that helps students dig up information independently (Sawangwan, 2024; Ruffinelli et al., 2023; Widodo et al., 2022). It is hoped that *ChatGPT* can function as a virtual tutor to support the learning process so that students are expected to use their creative and critical abilities more.

Creative thinking ability is a demand to create an idea or alternative solution to solve problems that occur in daily life. With creativity in learning, it is hoped that students will dare to solve problems using

their methods. So, students can make several alternative answers to solve the problem with the right solution (Monahan & Vaidya, 2023; Yaniawati, et al., 2020, 2021; Mubarika et al., 2022; Feb, 2022)

Critical thinking ability is a thinking skill that involves cognitive processes and invites students to think reflectively about problems. There are three critical thinking activities: investigation, interpretation, and decision-making. For *ChatGPT*, in order to help students work on TPS questions and practising creative and critical thinking skills to the maximum, it is necessary to have a model of how students can present questions that lead to the subject so that there are no misconceptions when *ChatGPT* receives the information (Gartland, 2024; Monteleone et al., 2023). One of the models is the *Probing-Prompting Model* (Halaweh, 2023; Jayanti & Rahmawati, 2018).

The probing-prompting model is a learning model that provides questions that lead to a subject that allows students to think higher to understand a material during learning. Probing prompting questions at the application level are given to students so that students are used to thinking critically, teaching aids are used in giving questions to make it easier to hone students' critical thinking skills, and then students are allowed to make conclusions from learning outcomes as a way to use the probing prompting learning model and then improve the level of critical thinking skills (Lee et al., 2024; Wiryanto, 2020; Usman et al., 2023)

METHOD

In this study, a mixed method is used, which is a mixture of qualitative and quantitative to provide a better understanding of how the role and evaluation of *ChatGPT* as a virtual tutor on creative and critical thinking skills are reviewed from students'

Probing-Prompting skills (Indrawan & Yaniawati, 2017). The design used is the insertion design (*The Embedded Design*). This design only reinforces the research process using a single method between qualitative and quantitative. Here are some of the stages of research carried out (Indrawan & Yaniawati, 2017) (See Appendix A, picture 1 and 2).

Judging from the objectives of this study, the data from the results of this study are how the answers obtained from *ChatGPT* and how the ability to prompt students with *ChatGPT* is qualitative. However, to strengthen the research conclusions, it is strengthened quantitatively so that it has a high level of confidence. The qualitative approach to this study is the grounded theory approach. *The Grounded Theory* method is built on a phenomenon and is structured to produce new theories. The theory is prepared using inductive data analysis. At the same time, the quantitative approach uses Pre-Experimental Design. The pre-experimental design focuses on the impact of changes in the behaviour of the observed research subjects without a control group. The one-group experimental design was used with pre-test and post-test (the one-group pretest-posttest design). Quantitative data was analysed to see if there was an improvement in students' mathematical, creative, and critical thinking skills after being treated with *ChatGPT* as a virtual tutor reviewed from *Probing-Prompting* skills (Deering & Williams, 2020; Oktaria et al., 2023; Punar et al., 2024; Putri et al., 2023; Saifuddin, 2020). The analysis used the Shapiro-Wilk Test to determine whether the data distribution was normal. Then, the Paired T-Test was used to compare the average of one group of paired data with a tab t-value of 0.025 (Silva et al., 2023).

The population in this study is all high school students who participate in

Tridaya Tutoring for the 2024/2025 Academic Year. The sample is part of the population selected for the study and is expected to be representative of the entire population. The sampling technique used is purposive sampling, which is a technique in which the researcher has the freedom to select samples according to specific criteria (Indrawan & Yaniawati, 2017). The selection of samples was carried out based on research materials, namely all grade XII high school students in the Tridaya Tutoring Program unit of Buah Batu, MTC, Suco, Antapani, Kopo, and Uber, with a total of 20 students. The characteristics of students are diverse, ranging from those who already understand learning well to those who still need more guidance to understand school material better.

RESULTS AND DISCUSSION

ChatGPT's ability as a virtual tutor in answering PKPM questions

Qualitative Analysis

AI-based chatbots began to emerge in November 2022, when *ChatGPT* was released to the public for the first time. This chatbot can answer any question we ask. This is an innovation, especially in the world of education, especially mathematics, where we are limited to a few applications if we want to know the answers to the questions given by *ChatGPT*, can be a virtual tutor for anyone studying without a learning schedule (Montenegro-Rueda et al., 2023; Jeon, 2024). This is because *ChatGPT* is open source, meaning anyone and anywhere can access it (Ding et al., 2023). Using a laptop or smartphone, we can ask for anything we want. However, the main question arises: Can *ChatGPT* answer simple to complex math problems? Is *ChatGPT* worthy of being used as

a virtual tutor to accompany and even replace the role of a teacher in the world of education?

Because the emergence of *ChatGPT* was only released at the end of 2022, there has not been much research, specifically in mathematics, on how effective *ChatGPT* is in answering the questions given. However, the findings from Lo CK in his 2023 paper entitled "*What is the Impact of ChatGPT on Education*" (Lo, 2023) revealed that *ChatGPT*'s performance was not satisfactory. Even so, the paper also revealed that *ChatGPT* can potentially be a virtual student tutor. This research can potentially contribute to expanding existing theories. The target of this study will reveal a new theory that has a relationship with the previous theory revealed by ole Lo CK based on field facts in detail based on the prompting ability of students and the results of the *ChatGPT* answers.

The data collected is in the form of screenshots of student prompting to *ChatGPT* along with the answers provided by *ChatGPT* based on question criteria. In this study, 10 PKPM questions were given, with 4 different material topics and different levels of difficulty, including numbers, measurements and geometry, data and

uncertainty, and algebra. Then, students prompted *ChatGPT* with several sample sections, including uploading questions or questions without optional options and uploading questions or questions with optional options. After the data is collected, data analysis is carried out based on a sample of the order of questions on each topic of the material. The data displayed results from prompting students to *ChatGPT* (See Appendix C, picture 3 to 10).

Quantitative Analysis

Quantitative data was analyzed to see if there was an improvement in students' mathematical, creative, and critical thinking skills after being treated with *ChatGPT* as a virtual tutor reviewed from *Probing-Prompting* skills. The analysis was carried out using the Shapiro-Wilk Test to determine whether the distribution of data was normal. Then, the paired t-test was used to compare the average of one data group with the help of SPSS and a tab t value of 0.025 (Arikunto, 1999). The hypothesis of the Paired T-Test is as follows (See Table 1 and 2) (Dhianti Putri et al., 2023).

Table 1. Results of Calculation of Paired T Test of Creative Ability

| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of Difference | | t | df | Sig. (2-tailed) |
|---|----------|----------------|-----------------|---------------------------------------|----------|-------|----|-----------------|
| | | | | Lower | Upper | | | |
| Pair 1 Before being given treatment – After being given treatment | - | 16.37553 | 3.66168 | - | - | - | 19 | .000 |
| | 24.50000 | | | 32.16398 | 16.83602 | 6.691 | | |

Table 2. Results of Calculation of Critical Ability Paired T Test

| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of Difference | | t | df | Sig. (2-tailed) |
|---|----------|----------------|-----------------|---------------------------------------|----------|-------|----|-----------------|
| | | | | Lower | Upper | | | |
| Pair 1 Before being given treatment – After being given treatment | - | 15.00877 | 3.35606 | - | - | - | 19 | .000 |
| | 24.00000 | | | 31.02432 | 16.97568 | 7.151 | | |

Discussion

ChatGPT's ability as a virtual tutor in answering PKPM questions

This research is to test ChatGPT's ability to answer PKPM questions. Based on the analysis that has been carried out, it was found that ChatGPT can answer questions either through prompting or only in the form of picture clippings. Students feel helped by the presence of this ChatGPT. They felt helped by some of the answers given. However, to upload questions with pictures was only limited to 2 pictures per day. This makes students need to be selective in asking ChatGPT which questions need to be asked along with pictures or not.

This is in line with what Korkmaz et al. said. that ChatGPT-4 is more successful in the exam compared to ChatGPT-3, version 5, is better at understanding the questions asked, better understands the instructions and includes more details in the solution of the questions, and at the same time, the two versions make common and different mistakes. According to the findings of the study, it was concluded that ChatGPT sometimes works very well, sometimes it only works well and sometimes it fails. Based on the findings of the study, it may be suggested to use the ChatGPT version in mathematics education to obtain basic information and to get supervised assistance. (Korkmaz Guler et al., 2024; Sapkota & Bondurant, 2024)

It is also in line with research from Lin who explains that by harnessing the power of AI, ChatGPT can help adult learners in setting learning goals, finding available resources, designing personalized learning plans, monitoring their performance, and reflecting on their learning experiences, ultimately leading to effective SDL completion (Lin, 2024). In addition to mathematics, in physics subjects

similar to mathematics to calculate problems, Ding et al. were tested. Specifically, the study tested ChatGPT's accuracy in answering physics questions, the relationship between students' level of trust in ChatGPT and the accuracy of their answers, and the effect of trust on students' perception of ChatGPT. Our findings show that while GenAI is not accurate in answering questions, most students trust its ability to provide correct answers. Trust in GenAI is also associated with students' perception of GenAI. In addition, the study highlights students' misconceptions about GenAI and provides suggestions for future consideration in AI literacy teaching and research (Ding et al., 2023).

Evaluation of ChatGPT as a virtual tutor in answering PKPM questions is reviewed from Probing-Prompting capabilities

ChatGPT provides the same steps when the questions given are only one way such as no 1 and 2 where the first question has been determined and the second question is in the form of a comparison. ChatGPT can provide different work steps for questions that measure student creativity, both in the form of multiple choice and essays. This provides a new perspective for students that working on problems is not only done through one way. Even though ChatGPT has been trained first, there are still mistakes in interpreting questions. For example, in question number 9, some students found that ChatGPT misinterpreted the question even though the prompting was the same. The slightest mistake in prompting, especially in writing equations and signs, will affect the answers given by ChatGPT. Students feel helped by the presence of ChatGPT as a virtual tutor because they can learn independently anytime and anywhere without disturbing their teachers. However, they are not satisfied with the results of

ChatGPT's answers because they need answers to more complicated and complex questions

This is in line with previous research that academics were also aware that the use of ChatGPT raises concerns, such as inaccurate, unreasonable, or unclear outputs. We, two math teacher educators, engaged in a collaborative self-study using a qualitative descriptive approach to investigate the procedures, concepts, and cognitive demands of ChatGPT-generated math tasks that focused on fractional multiplication using an area model approach. We found that the tasks generated by ChatGPT are mostly procedural and not cognitively demanding. We suggest that educators do not rely entirely on ChatGPT to generate fractional multiplication tasks that demand cognitive abilities by using area models. We offer recommendations for educators to use ChatGPT strategically to generate math tasks that demand cognitive abilities. Aligned with Newton & Xiromeriti, that ChatGPT underperforms and fails most multiple-choice exams, performing much worse than the average human student. These findings suggest that all summative MCQ-based assessments should be conducted under secure conditions with limited access to ChatGPT and similar tools, specifically exams that assess basic knowledge (Sapkota & Bondurant, 2024; Newton & Xiromeriti, 2024)

The need for good prompt ability to communicate is explained by Mustafa & Saadi. This research discusses the important role of prompt development as an important skill for university instructors engaged with ChatGPT. The results highlight the flexibility of the formula and its potential applications in a variety of areas, from syllabus planning to assessment. The limitations inherent in ChatGPT, emphasized the need for instructors to be cautious in their use and underscored the

ever-evolving AI landscape in education (Nazari & Saadi, 2024).

The Influence of ChatGPT as a Virtual Tutor in Improving Students' Creative & Critical Mathematical Thinking Skills Reviewed from Probing-Prompting Skills

Creative thinking is the process of thinking to increase possibilities, postpone considerations, provide new and unusual possibilities, use imagination and intuition, develop and choose alternatives, and have many ways and use different viewpoints or answers to something. Meanwhile, critical thinking skills are thinking skills that involve cognitive processes and invite students to think reflectively about problems. In this context, students will be seen the ability to think extensively, originality, and the ability to elaborate ideas in addition, students will be seen three activities in critical thinking, namely investigation, interpretation, and decision-making. The results of the study show that in their prompting ability, students only copy answers, send images in the form of questions to ChatGPT. Students are not creative in asking questions. However, when students are given different answers or there are no answers in the choices, students immediately ask the teacher why this happens. Then, students also validate by looking for answers with material that the teacher has instructed (Surya, 2015; Saputra, 2020; Ennis & Weir, 1985).

This is in line with Niloy et al. which reveals a detrimental relationship between the use of ChatGPT and students' creative writing abilities. Machine-based and human-based assessment analysis reinforces previous qualitative observations regarding the adverse impact of ChatGPT on creative writing. The study highlights the need for a cautious approach to AI integration, particularly in the discipline of

creative writing. While AI tools have their advantages, their integration must be done carefully, considering their potential drawbacks (Niloy et al., 2024).

In addition, it is in line with research from Barana et al. The results show that all problem-solving strategies and all phases of critical thinking can be affected by this kind of activity, as students must check the correctness of ChatGPT's solutions, not always true, or check their own solutions through ChatGPT. In addition, the activity also helps them find new and different approaches to solve problems (Barana et al., 2023).

Although it has a negative impact on the prompting, the answers from ChatGPT provided have an impact on students in improving their students' answer creativity skills. This is shown from the different students' answers in answering the questions, the results of the posttest also show an increase in student scores from the pretest. In addition, this is supported by the results of the T Test which found that the thit result of 6,691 exceeded the ttab.

Implication of Research

The findings regarding ChatGPT's errors in interpreting questions, especially complex questions or requiring a deep understanding of context, show that AI still has limitations in understanding the nuances of complex language and contexts. This indicates the need for the development of more sophisticated AI models to be able to overcome this challenge. Although ChatGPT can be helpful in the learning process, the results of the study show that the role of human teachers and tutors is still very important to provide comprehensive guidance, clarification, and evaluation.

ChatGPT can be an effective tool in

learning math, especially to provide instant feedback and diverse sample questions. However, it is important to provide students with clear guidance on how to use ChatGPT effectively and critically. The results of the research can be the basis for the development of a curriculum that integrates the use of AI such as ChatGPT, while still paying attention to its limitations and emphasizing the importance of critical and creative thinking.

Limitation

The limitation of the problem in this study is how the role of ChatGPT can answer general or complex questions, especially in TPS questions. In addition, there needs to be an evaluation because it is basically made different from the application that is usually used in answering questions. Then how to communicate between students and ChatGPT. Finally, can this ChatGPT affect the improvement of students' critical and creative thinking.

CONCLUSION

Based on the results and discussion above, it can be concluded that from the point of view of use, ChatGPT can help students in learning as a virtual tutor. However, it is also necessary to pay attention because not all questions can be answered all, and there are even some who have different answers, especially in working on questions that are complicated and complex. This makes students dissatisfied with the results obtained. This is where students are trained in critical thinking about why this can happen. In addition, student prompting techniques against ChatGPT are also considered. There is a need for creativity in prompting so that students can further explore the answers from ChatGPT. Although it can answer any question, in the end, there

needs to be guidance from experts (in this context, teachers) and independent verification of the answers that have been provided by ChatGPT so that the desired answers are in line with expectations

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Appendix A of article entitled The Role and Evaluation of ChatGPT as a Virtual Tutor in Improving Students' Creative and Critical Abilities Reviewed from Probing-Prompting Abilities

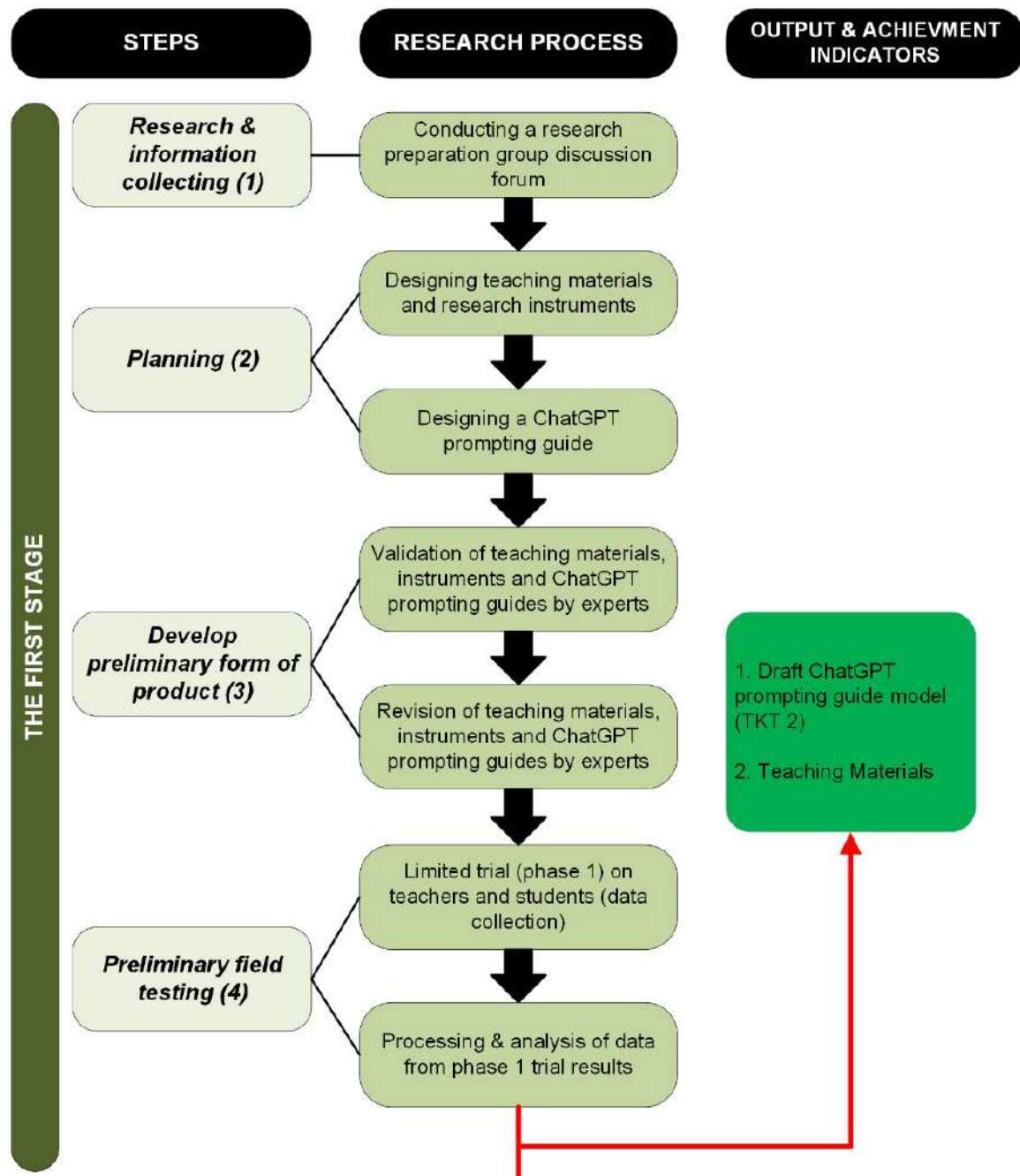


Figure 1. First Stage of Research

Appendix B of article entitled The Role and Evaluation of ChatGPT as a Virtual Tutor in Improving Students' Creative and Critical Abilities Reviewed from Probing-Prompting Abilities

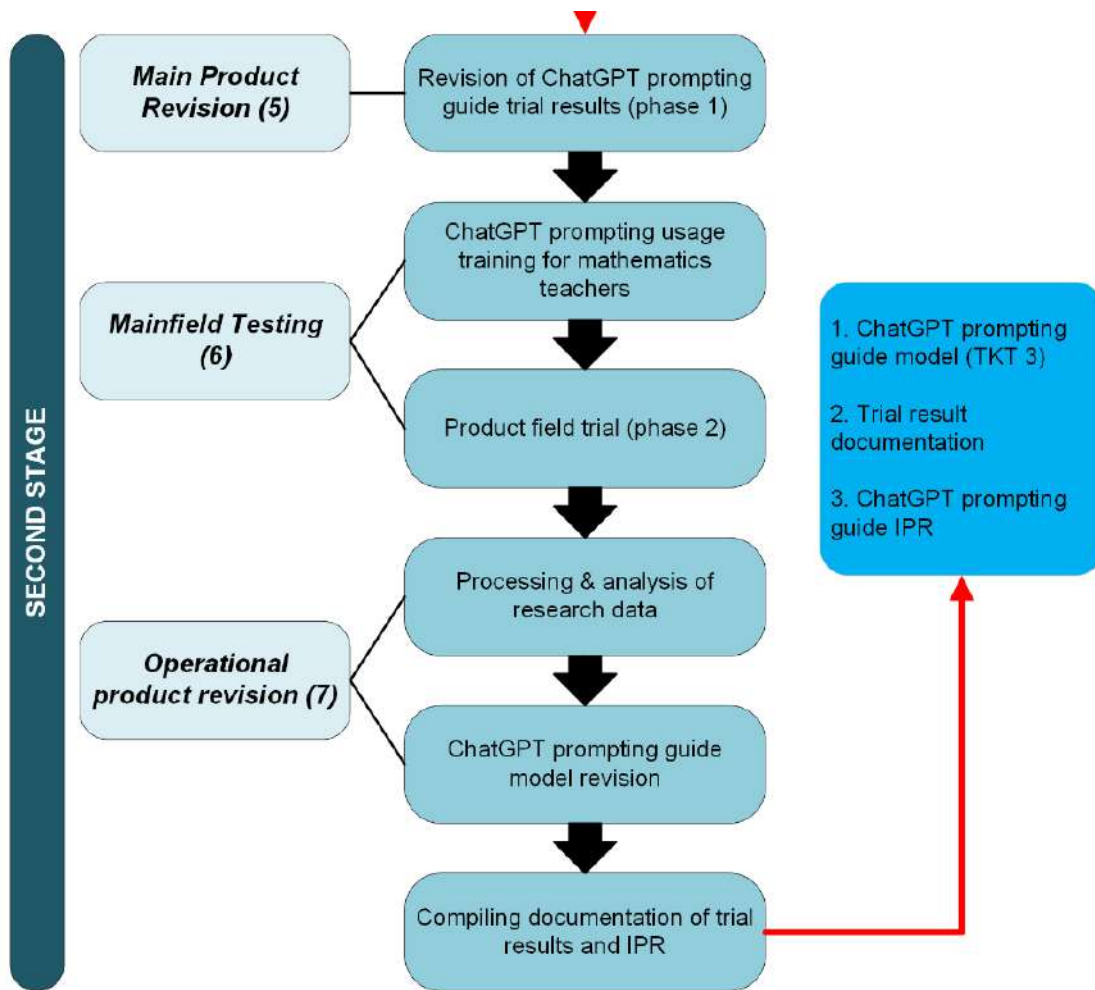



Figure 2. Second Phase of Research

Appendix C of article entitled The Role and Evaluation of ChatGPT as a Virtual Tutor in Improving Students' Creative and Critical Abilities Reviewed from Probing-Prompting Abilities

1. Numbers



Untuk setiap bilangan j dan k , didefinisikan $j \# k = j - k + 3$, nilai dari $(3 \# 6) \# 2$ adalah...

Untuk menyelesaikan soal ini, kita harus mengikuti definisi operasi yang diberikan:

- Hitung $3 \# 6$ menggunakan rumus $j \# k = j - k + 3$.

$$3 \# 6 = 3 - 6 + 3 = 0$$
- Sekarang, hitung $0 \# 2$.

$$0 \# 2 = 0 - 2 + 3 = 1$$

Jadi, nilai dari $(3 \# 6) \# 2$ adalah 1.

Kirim pesan ke ChatGPT

For every number j and k , we define $j \# k = j - k + 3$. The value of $(3 \# 6) \# 2$ is...

To solve this problem, we need to follow the definition of the operation given:

1. Calculate $3 \# 6$ using the formula $j \# k = j - k + 3$

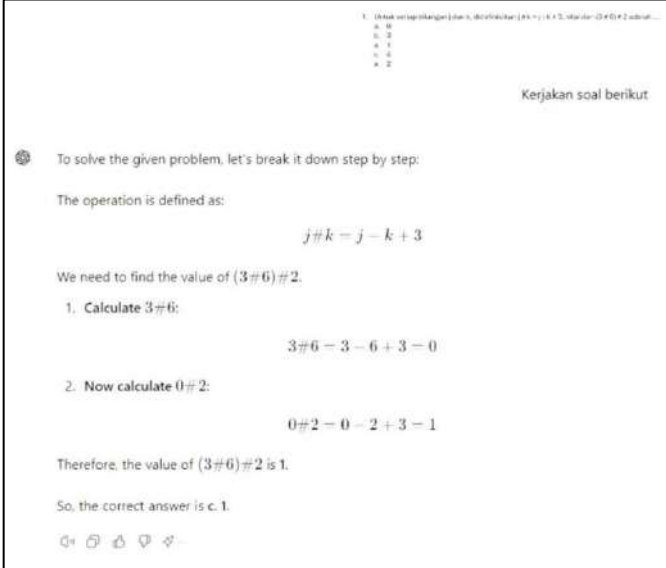
$$3 \# 6 = 3 - 6 + 3 = 0$$

2. Now, calculate $0 \# 2$

$$0 \# 2 = 0 - 2 + 3 = 1$$

So, the value of $(3 \# 6) \# 2$ is 1.

Figure 3. ChatGPT's answer when uploading a question or number question without an option



1. Untuk setiap bilangan j dan k , didefinisikan $(j \# k) = j - k + 3$, nilai dari $(3 \# 6) \# 2$ adalah...

a. 0
b. 2
c. 1
d. 3

Kerjakan soal berikut:

To solve the given problem, let's break it down step by step:

The operation is defined as:

$$j \# k = j - k + 3$$

We need to find the value of $(3 \# 6) \# 2$.

- Calculate $3 \# 6$:

$$3 \# 6 = 3 - 6 + 3 = 0$$
- Now calculate $0 \# 2$:

$$0 \# 2 = 0 - 2 + 3 = 1$$

Therefore, the value of $(3 \# 6) \# 2$ is 1.

So, the correct answer is c. 1.

Figure 4 ChatGPT's answer when uploading a question or number problem with optional options

2. Numbers

Jika $d_1 = \frac{1}{3} d_2$ dan $d_2 = \frac{3}{2}$ sisi persegi, maka keliling dari layang-layang adalah...

Dari gambar yang diberikan, layang-layang tersebut dibentuk oleh dua diagonal, d_1 dan d_2 . Berdasarkan informasi yang diberikan:

- $d_1 = \frac{1}{3} d_2$
- $d_2 = \frac{3}{2}$ panjang sisi persegi, yaitu 22 cm.

Langkah-langkahnya adalah sebagai berikut:

- Hitung panjang d_2 :

$$d_2 = \frac{3}{2} \times 22 \text{ cm} = 33 \text{ cm}$$
- Hitung panjang d_1 menggunakan hubungan $d_1 = \frac{1}{3} d_2$:

$$d_1 = \frac{1}{3} \times 33 \text{ cm} = 11 \text{ cm}$$
- Karena sisi-sisi layang-layang adalah segitiga siku-siku yang terbentuk dari setengah dari diagonal-diagonalnya, maka panjang setiap sisi (misalkan s) bisa dihitung menggunakan teorema Pythagoras:

$$s = \sqrt{\left(\frac{d_1}{2}\right)^2 + \left(\frac{d_2}{2}\right)^2}$$

$$s = \sqrt{\left(\frac{11}{2}\right)^2 + \left(\frac{33}{2}\right)^2}$$

$$s = \sqrt{\left(\frac{121}{4}\right) + \left(\frac{1089}{4}\right)}$$

$$s = \sqrt{\frac{121 + 1089}{4}} = \sqrt{\frac{1210}{4}} = \sqrt{302.5} \approx 17.4 \text{ cm}$$
- Keliling layang-layang adalah dua kali jumlah dari dua sisi yang berbeda:

$$\text{Keliling} = 2 \times (s + d_1) = 4s \approx 4 \times 17.4 \text{ cm} = 69.6 \text{ cm}$$

Jadi, keliling dari layang-layang tersebut adalah 69.6 cm.

If $d_1 = \frac{1}{3} d_2$ and $d_2 = \frac{3}{2}$ the side of the square, then the perimeter of the kite is...

Based on the given diagram, the kite is formed by two diagonals, d_1 and d_2 . Based on the given information:

- $d_1 = \frac{1}{3} d_2$
- $d_2 = \frac{3}{2}$ the length of the side of the square, which is 22 cm

The steps are as follows:

- Calculate the length of d_2 :

$$d_2 = \frac{3}{2} \times 22 \text{ cm} = 33 \text{ cm}$$
- Calculate the length of d_1 using the relationship $d_1 = \frac{1}{3} d_2$:

$$d_1 = \frac{1}{3} \times 33 \text{ cm} = 11 \text{ cm}$$
- Because the sides of the kite are right-angled triangles formed from half of the diagonals, then the length of each side (for example, a) can be calculated using the Pythagorean theorem:

$$s = \sqrt{\left(\frac{d_1}{2}\right)^2 + \left(\frac{d_2}{2}\right)^2}$$

$$s = \sqrt{\left(\frac{11}{2}\right)^2 + \left(\frac{33}{2}\right)^2}$$

$$s = \sqrt{\left(\frac{121}{4}\right) + \left(\frac{1089}{4}\right)}$$

$$s = \sqrt{\frac{121 + 1089}{4}}$$

$$s = \sqrt{302.5} \approx 17.4 \text{ cm}$$
- The perimeter of the kite is twice the sum of two different sides.

$$\text{Perimeter} = 2 \times (s + d_1) = 4s = 4 \times 17.4 \text{ cm} = 69.6 \text{ cm}$$

Therefore, the perimeter of the kite is 69.6 cm.

Figure 5. ChatGPT's answers when uploading measurement & geometry questions or questions without the option

4. Jika $d_1 = \frac{1}{3} d_2$ dan $d_2 = \frac{3}{2}$ sisi persegi, keliling layang-layang:

- Misalkan sisi persegi = s , maka $d_2 = \frac{3}{2} s$, dan $d_1 = \frac{1}{3} \times \frac{3}{2} s = \frac{1}{2} s$.
- Keliling layang-layang = $2(d_1 + d_2) = 2 \times \left(\frac{1}{2} s + \frac{3}{2} s\right) = 2s$.

Misalkan $s = 33$, keliling layang-layang adalah 66.

Jawaban: c. 66

4. If $d_1 = \frac{1}{3} d_2$ and $d_2 = \frac{3}{2}$ the side of the square, the perimeter of the kite is:

- Let's say the side of the square is s , then $d_2 = \frac{3}{2} s$, and $d_1 = \frac{1}{3} \times \frac{3}{2} s = \frac{1}{2} s$.
- The perimeter of the kite = $2(d_1 + d_2) = 2 \times \left(\frac{1}{2} s + \frac{3}{2} s\right) = 2s$.

For example, if $s = 33$, the perimeter of the kite is 66.
Answer: c. 66

Figure 6. ChatGPT's answers when uploading measurement & geometry questions or questions with optional options

3. Data & Uncertainty

| | |
|---|--|
| <p>8. Peluang Pak Eko Bramantyo suka bubur tidak diaduk</p> <p>Diketahui:</p> <ul style="list-style-type: none"> • Total orang: 100 • Yang suka bubur diaduk: Laki-laki = 7, Perempuan = ? • Yang suka bubur tidak diaduk: Laki-laki = ?, Perempuan = 23 • Total suka bubur tidak diaduk = 58 <p>Jumlah yang suka bubur tidak diaduk adalah 58 orang. Dari tabel, 23 orang adalah perempuan, maka jumlah laki-laki yang suka bubur tidak diaduk:</p> $58 - 23 = 35 \text{ laki-laki}$ <p>Total laki-laki adalah 40 orang, jadi jumlah laki-laki yang suka bubur diaduk adalah:</p> $40 - 35 = 5 \text{ laki-laki}$ <p>Sekarang, peluang Pak Eko Bramantyo (sebagai salah satu dari 100 orang) suka bubur tidak diaduk adalah:</p> $\text{Peluang} = \frac{\text{Jumlah orang suka bubur tidak diaduk}}{\text{Total orang}} = \frac{58}{100} = 58\%$ <p>Namun, kita diminta mencari peluang jika dia sudah berada dalam 42%, lebih ke tabel yang benar.</p> | <p>The probability of Mr. Eko Bramantyo liking porridge that is not stirred</p> <p>Given:</p> <ul style="list-style-type: none"> - Total people: 100 - Those who like stirred porridge: men = ?, women = ? - Those who like unstirred porridge: men: 2 = ? Women: 23 - Total who likes unstirred porridge: 58 <p>The number of people who like unstirred porridge is 58 people. From the table, 23 people are women, so the number of men is:</p> <p>58 - 23 = 35 men.</p> <p>The total number of men is 40 people, so the number of men is:</p> <p>40 - 35 = 5 men.</p> <p>Now, the probability of Mr. Eko Bramantyo (as one of 100 people) liking unstirred porridge is:</p> <p>Probability = Number of people who like unstirred porridge / Total people = 58/100 = 58%</p> |
|---|--|

Figure 7. ChatGPT's answers when uploading questions or data & uncertainty questions without the option


| | |
|---|--|
|  <p>Dari gambar soal nomor 8, berikut adalah informasi yang tersedia:</p> <ul style="list-style-type: none"> • Ramon melakukan survei pada penumpang Transjakarta dan mengumpulkan data terkait preferensi tentang bubur diaduk atau tidak diaduk. • Tabel survei menunjukkan data jumlah laki-laki dan perempuan, tetapi ada beberapa bagian yang belum diisi. • Total orang yang disurvei adalah 100 orang, di mana 58 orang suka bubur diaduk dan 23 orang suka bubur tidak diaduk. • Pertanyaannya adalah tentang peluang Pak Eko Bramantyo suka bubur tidak diaduk. <p>Untuk menghitung peluang Pak Eko Bramantyo suka bubur tidak diaduk:</p> <ul style="list-style-type: none"> • Total orang yang tidak suka bubur diaduk adalah 23. • Total orang yang disurvei adalah 100. <p>Maka, peluang Pak Eko Bramantyo suka bubur tidak diaduk adalah:</p> $P = \frac{23}{100} = 0,23$ <p>Jadi, peluangnya adalah 23%.</p> | <p>From question number 8, the following information is available:</p> <ul style="list-style-type: none"> - Ramon conducted a survey on Transjakarta passengers and collected data related to preferences regarding stirred or unstirred porridge. - The survey table shows the number of men and women, but some parts are still blank. - The total number of people surveyed is 100, of which 58 people like stirred porridge and 23 people like unstirred porridge. - The question is about the probability of Mr. Eko Bramantyo liking unstirred porridge. <p>To calculate the probability of Mr. Eko Bramantyo liking unstirred porridge:</p> <ul style="list-style-type: none"> - The total number of people who like unstirred porridge is 23. - The total number of people surveyed is 100. <p>Therefore, the probability of Mr. Eko Bramantyo liking unstirred porridge is:</p> $P = 23/100 = 0.23$ |
|---|--|

Figure 8. ChatGPT's answers when uploading questions or data & uncertainty questions with optional options

4. Algebra

Diketahui $x < 0$. Manakah hubungan yang benar antara kuantitas P dan Q berikut berdasarkan informasi yang diberikan?

Untuk membandingkan nilai dari P dan Q , kita perlu menganalisis bentuk aljabarnya.

Diketahui:

$$P = \frac{3^x + 1}{9^x - 1}$$

dan

$$Q = \frac{1}{3^x}$$

Karena $x < 0$, mari kita pecahkan masalah ini langkah demi langkah.

Langkah 1: Menyederhanakan P

Ingat bahwa 9^x dapat ditulis sebagai $(3^2)^x = 3^{2x}$. Sehingga:

$$P = \frac{3^x + 1}{3^{2x} - 1}$$

Langkah 2: Analisis untuk Q

Diberikan:

$$Q = \frac{1}{3^x}$$

Karena $x < 0$, maka 3^x adalah bilangan pecahan antara 0 dan 1. Dengan demikian, Q menjadi bilangan yang lebih besar dari 1.

Langkah 3: Membandingkan P dan Q

- Nilai P : Karena 3^x adalah bilangan positif yang lebih kecil dari 1 untuk $x < 0$, maka pembilang $3^x + 1$ akan mendekati 1. Penyebut $3^{2x} - 1$ adalah bilangan negatif karena 3^{2x} mendekati 0, sehingga P adalah bilangan negatif.
- Nilai Q : Sebaliknya, $Q = \frac{1}{3^x}$ akan bernilai positif dan lebih besar dari 1 karena 3^x adalah bilangan kecil.

Kesimpulan:

- P adalah bilangan negatif.
- Q adalah bilangan positif lebih besar dari 1.

Jadi, kuantitas Q lebih besar dari kuantitas P .

Solusi persamaan P dan Q ? Bisa jelaskan lagi petuang?

Message ChatGPT

Given $P = (3^x + 1) / (9^x - 1)$ and $Q = 1 / (2x)$, where $x < 0$, which of the following relationships between P and Q is correct based on the given information?

To compare the values of P and Q , we need to analyze the algebraic form.

Given:

$$P = (3^x + 1) / (9^x - 1)$$

and

$$Q = 1 / (2x)$$

Step 1: Simplifying P

Recall that 9^x can be written as $(3^2)^x = 3^{2x}$.

Therefore:

$$P = (3^x + 1) / (3^{2x} - 1)$$

Step 2: Analysis for Q

Given:

$$Q = 1 / (2x)$$

Since $x < 0$, 3^x is a fraction between 0 and 1. Thus, Q becomes a number greater than 1.

Step 3: Comparing P and Q

- Value of P : Because $x < 0$, the numerator $(3^x + 1)$ is less than 1, and the denominator $(3^{2x} - 1)$ is negative. Therefore, P is negative.
- Comparison: Since P is negative and Q is greater than 1, we can conclude that $Q > P$.

Therefore, the correct relationship between P and Q is $Q > P$.

Figure 9. ChatGPT's answer when uploading an algebra question or question without an option

9. Relationship Between Quantities P and Q

Given $x < 0$:

$$P = \frac{3x + 1}{x - 1}, \quad Q = \frac{1}{3 - x}$$

Since $x < 0$, the relationship between P and Q cannot be directly determined without specific values of x .

Answer:

d. The information provided is not sufficient to determine the relationship between quantities P and Q .

Message ChatGPT

Figure 10. ChatGPT's answer when uploading an algebra question or problem with optional options



Technology Integration in Learning Design to Improve PGMI Students' Mathematical Communication Skills on the Concept of Integers

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Abstract

The development of technology encourages the world of education to be able to integrate it into learning design. By integrating technology into learning, students not only get more sophisticated tools to understand and manage mathematical concepts, but also strengthen their skills in communicating mathematical ideas clearly and effectively so that able to support the development of students' mathematical communication skills. Therefore, prospective elementary school teachers must prepare themselves to face the challenges of education in a better digital era. This study aims to analyze the effectiveness of technology integration such as YouTube, Kahoot, and PHET in learning design to improve mathematical communication skills of elementary school teacher education program (PGMI) students on the concept of integers. The type of research used is a quantitative approach with a quasi-experimental method with a posttest-only control design. The posttest-only control design was chosen for this study because the focus is on a direct comparison of the results between the experimental group and the control group after the treatment was given. The sample in this study involved 74 PGMI students who were divided into 38 students in the experimental group and 36 students in the control group. The experimental group received learning with technology integration, while the control group used conventional methods. Data were collected through a mathematical communication skills test. Data analysis used descriptive and inferential statistics, namely the independent sample t-test. The results showed that there were differences in the mathematical communication skills of the experimental group compared to the control group. The experimental group showed better abilities in terms of compiling mathematical arguments, using mathematical symbols and terms clearly, and effectiveness in explaining the concept of integers. Technology integration in learning has proven effective in improving students' mathematical communication skills on the topic of integers. These findings provide practical implications that the integration of technology in learning needs to be optimized to support mathematics learning in the digital era. Prospective teachers need to be prepared with the skills to use technology in learning design.

Keywords: Technology integration, Communication Skills, Learning Design

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Abstrak

Perkembangan teknologi mendorong dunia pendidikan untuk dapat mengintegrasikannya dalam desain pembelajaran. Dengan mengintegrasikan teknologi ke dalam pembelajaran, mahasiswa tidak hanya mendapatkan alat yang lebih canggih untuk memahami dan mengelola konsep matematika, tetapi juga memperkuat keterampilan mereka dalam mengomunikasikan ide-ide matematika secara jelas dan efektif sehingga mampu mendukung pengembangan kemampuan komunikasi matematis mahasiswa. Untuk itu, calon guru sekolah dasar harus mempersiapkan diri dalam menghadapi tantangan pendidikan di era digital yang lebih baik. Penelitian ini bertujuan untuk menganalisis efektivitas integrasi teknologi such as YouTube, Kahoot, and PhET dalam desain pembelajaran untuk meningkatkan kemampuan komunikasi matematis mahasiswa Program Studi Pendidikan Guru Madrasah Ibtidaiyah (PGMI) pada konsep bilangan bulat. Adapun jenis penelitian yang digunakan ialah pendekatan kuantitatif dengan metode quasi eksperimen dengan desain kontrol posttest-only. Desain kontrol posttest-only dipilih untuk penelitian ini karena fokusnya adalah pada perbandingan langsung hasil akhir antara kelompok eksperimen dan kelompok kontrol setelah perlakuan diberikan. Adapun sampel dalam penelitian ini melibatkan 74 mahasiswa PGMI yang dibagi menjadi 38 mahasiswa kelompok eksperimen dan 36 mahasiswa kelompok kontrol. Kelompok eksperimen menerima pembelajaran dengan integrasi teknologi, sementara kelompok kontrol menggunakan metode konvensional. Data dikumpulkan melalui tes kemampuan komunikasi matematis. Analisis data menggunakan statistik deskriptif dan inferensial, yakni uji – t independent sampel t-test. Hasil penelitian menunjukkan terdapat perbedaan dalam kemampuan komunikasi matematis kelompok eksperimen dibandingkan kelompok kontrol. Kelompok eksperimen menunjukkan kemampuan yang lebih baik dalam hal menyusun argumen matematis, penggunaan simbol dan istilah matematika secara jelas, serta keefektifan dalam menjelaskan konsep bilangan bulat. Integrasi teknologi dalam pembelajaran terbukti efektif dalam meningkatkan kemampuan komunikasi matematis mahasiswa pada topik bilangan bulat. Temuan ini memberikan implikasi praktis bahwa integrasi teknologi dalam pembelajaran perlu dioptimalkan untuk mendukung pembelajaran matematika di era digital. Selain itu, calon guru perlu dipersiapkan dengan keterampilan menggunakan teknologi dalam desain pembelajaran.

INTRODUCTION

The continuous advancement of the digital era has rendered the integration of technology in education indispensable, shifting it from a discretionary choice to an essential component of modern pedagogy (Srivastava & Srivastava, 2024). The incorporation of digital technology into the learning process brings about significant changes in educational methods. By utilizing digital technology, students can experience a more realistic learning experience (Haleem et al., 2022). Especially In the discipline of mathematics education, the use of technology can open new opportunities to improve learning effectiveness.

Therefore, technology is crucial for teachers and prospective teachers, including PGMI students, to understand and master technology to utilize it effectively in the learning process (Fauzan et al., 2022); By

achieving this mastery, they can maximize the potential of technology to enhance mathematics learning (Trisnawati et al., 2023).

Mathematics is an important subject and must be taught to all students, from elementary school to college level. The goal is to develop logical, analytical, structured, and critical thinking skills (Raxmonjonovich & O'sarovna, 2023). According to Fadilla et al., (2021), mathematics is a discipline with distinctive characteristics, consisting of logically structured concepts with relationships established through valid proofs. Currently, the use of technology in learning has become indispensable, as it can bring significant changes to teaching methods and help develop mathematical skills in a more effective and engaging way (Engelbrecht & Borba, 2024).

The correlation between concepts in mathematical material requires students to

be able to explain both the relationships and differences among these concepts. This ability is part of communication skills. Mathematical communication skills are one of the main competencies that students must have, includes PGMI (Rahman et al., 2024). Mathematical communication skills are essential competencies that PGMI students must develop. These skills encompass the ability to express and interpret mathematical ideas both verbally and in writing, utilizing various forms such as tables, diagrams, pictures, formulas, or demonstrations (Anggriani & Septian, 2019; Soleh et al., 2020). Mathematical communication is elaborated in written and verbal that demonstrate clarity of ideas and concepts in mathematical content (Hodiyanto, 2017). Mathematical communication skills are abilities characterized by the ability to express mathematical ideas and concepts in a logical sequence (Morgan, 2020). The indicators used to assess students' mathematical communication skills are adopted from the mathematical communication standards proposed by NCTM in 2000 (NCTM, 2000). The indicators of mathematical communication skills used in this study are: (1) Consolidating mathematical ideas or concepts in writing; (2) Interpreting mathematical ideas or concepts through graphs, images, or tables; and (3) Accurately expressing mathematical concepts.

Effective communication skills are essential not only for personal understanding among PGMI students but also for preparing them to become future educators capable of explaining mathematical concepts clearly and effectively to elementary school students (Uyen et al., 2021). However, the reality in the field shows that the mathematical communication skills of PGMI students, especially in written form, are still

relatively low. The results of previous studies revealed that students often have difficulty in conveying mathematical ideas coherently and systematically (Nadlifah & Prabawanto, 2017; Maulyda et al., 2020; Turmuzy et al., 2021). This limitation poses a significant challenge in mathematics learning, necessitating innovative solutions to address it.

One potential approach to overcoming this challenge is through the implementation of technology integration in learning design. The presence of technology-based media is expected to provide solutions to various challenges encountered in the field of education (Windasari et al., 2024). Technology-based media such as e-learning, educational applications, other digital platforms (such as YouTube, Kahoot, and PhET) have become essential tools in supporting the learning process in this digital era (Suharli et al., 2024). Several previous studies have shown the effectiveness of technology integration in learning. For example, Backfisch et al., (2021) highlighted that technologies play a critical role in integrating technology in a qualitatively high manner that largely depends on the particular context. In the context of mathematical communication skills, Ompusunggu & Sari (2019) and Sudihartini et al., (2021) identified a significant increase in students who use technology to understand identified a significant improvement in students who used technology to understand and articulate mathematical ideas, particularly through digital-based educational applications.

However, studies that explore the influence of technology integration on mathematical communication skills, especially in PGMI students and in the topic of integers, are still limited. This study offers a new contribution by investigating in more depth how technology can be effectively

integrated into mathematics learning design.

Based on this background, this study aims to explore how technology integration in learning design can improve mathematical communication skills of PGMI students, especially in understanding and explaining the concept of integers. This study will investigate various strategies and innovative approaches in integrating technology into the PGMI curriculum, as well as analyzing its impact on the development of students' mathematical communication skills. By understanding how technology can be effectively integrated to support the development of mathematical communication skills, it is expected to prepare prospective elementary school teachers to face the challenges of education in the digital era better. The findings of this research can serve as a foundation for developing more effective PGMI curriculum that equips future teachers to teach mathematics in the digital era, while also providing valuable insights for educators and policymakers to improve the quality of mathematics education at the higher education level.

METHODS

This study uses a quantitative research type with a quasi-experimental method. This design has a control group, but it cannot fully function to control external variables that affect the implementation of the experiment (Sugiyono, 2020).

The sample in this study was 74 PGMI students, involving two classes of PGMI students, each consisting of 36 control class students and 38 experimental class students who were selected purposively.

The design used was a posttest-only control design which is described in Table 1.

Table 1. Research design

| Group | Treatment | Posttest |
|------------|-----------|----------|
| Experiment | X | T |
| Control | | T |

This posttest only control design research design emphasizes the comparison of treatments between the two groups: the control group and the experimental group, where the experimental group is the group given special treatment, in this study the use of integrated technology media while the control group did not receive special treatment, only using ordinary methods. Therefore, the conclusion regarding the effect of independent variables on the dependent variable is more accurate because both groups are equal (Lee, 2022).

The independent variable in this study is the integration of technology in learning design, with mathematical communication skills as the dependent variable, focusing on the concept of integers. The research instruments include mathematical communication skills tests, observation sheets, and student response questionnaires.

The concept presented in this lecture is the sub-topic of numbers. The pretest and posttest questions are the same. The integration of technology in learning design is in the form of digital media such as e-learning, You Tube, Kahoot, and Phet.

The procedure includes preparation of instruments, implementation of learning with different treatments in experimental and control groups, and data collection through pretest and posttest. Data analysis uses descriptive and inferential statistics, including prerequisite tests (normality and homogeneity) and hypothesis testing such as independent t-test or Mann-Whitney U test.

RESULTS AND DISCUSSION

Result

This study descriptively examines the mathematical communication skills of PGMI students regarding the concept of integers. It compares those who received technology-integrated learning with those who experienced conventional learning, followed by inferential statistical tests to validate the findings.

Description of PGMI Students' Mathematical Ability Results

Based on the research results, the posttest values obtained for the control group, which utilized conventional learning methods, and the experimental group, which employed technology-integrated learning for the concept of integers, are presented in Tables 2 and 3:

Table 2 Descriptive Statistics of Control Class Posttest

| Statistics | Posttest |
|--------------------|----------|
| Lowest score | 60.00 |
| The highest score | 91.00 |
| Average | 64.33 |
| Standard Deviation | 5.63 |

Tabel 3 Descriptive Statistics of Experiment Class Posttest

| Statistics | Posttest |
|--------------------|----------|
| Lowest score | 65,00 |
| The highest score | 100,00 |
| Average | 80,26 |
| Standard Deviation | 6,77 |

Based on tables 2 and 3 above, it shows that the mathematical communication skills of PGMI students in the control class are still relatively low with an average of 64.33 with a sample size of 36, the lowest

value of 60 and the highest of 91 and a standard deviation of 5.63. While the mathematical communication skills of PGMI students in the experimental class are relatively high with an average of 80.26 with a sample size of 38, the lowest value of 65 and the highest of 100 and a standard deviation of 6.77. From the two posttest values, the average in the experimental class is higher with a difference of 15.93 compared to the control class, in addition the lowest value in the experimental class is higher with a difference of 5 points and a difference of 9 points for the highest value.

Students mathematical communication skills are grouped into very low, low, medium, high and very high categories. The frequencies and percentages obtained after the posttest are as follows:

Table 4 Result of Mathematical Communication Skills in Control Class

| Interval | Category | Posttest | |
|----------|-----------|-----------|----------------|
| | | Frequency | Percentage (%) |
| 0 – 54 | Very low | 0 | 0 |
| 55 – 64 | Low | 14 | 39 |
| 65 – 79 | Medium | 21 | 58.3 |
| 80 – 89 | High | 0 | 0 |
| 90 – 100 | Very high | 1 | 2.7 |
| Amount | | 36 | 100 |

Table 5 Results of Mathematical Communication Ability in Experimental Class

| Interval | Category | Posttest | |
|----------|-----------|-----------|----------------|
| | | Frequency | Percentage (%) |
| 0 – 54 | Very low | 0 | 0 |
| 55 – 64 | Low | 0 | 0 |
| 65 – 79 | Medium | 14 | 37 |
| 80 – 89 | High | 19 | 50 |
| 90 – 100 | Very high | 5 | 13 |
| Jumlah | | 38 | 100 |

Based on table 4 and 5 above, the posttest value of the mathematical communication ability of PGMI students in the control class is dominated by the medium category with a percentage of 58.3%, there

are 14 students in the low category with a percentage of 39% and there is 1 person in the very high category with a percentage of 2.7%. While the posttest value of the mathematical communication ability of PGMI students in the experimental class is dominated by the high category with a percentage of 50%, there are 14 students in the medium category with a percentage of 37% and there are 5 students in the very high category with a percentage of 13% and none are in the very low or low category.

The posttest results of students between the control class and the experimental class can be seen in Figure 1.

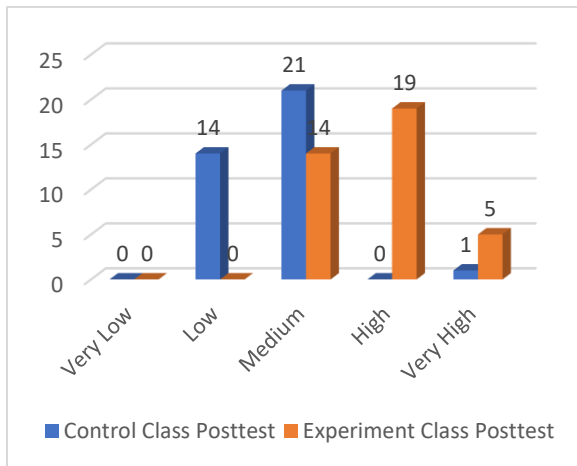


Figure 1. Results of the posttest of mathematical communication skills

Based on the results of the analysis, it can be concluded that there is a difference in the average mathematical communication skills of PGMI students between classes

that use technology-integrated learning and classes that use conventional learning.

The effectiveness of learning with technology integration in improving mathematical communication skills of PGMI students

This section evaluates the effectiveness of technology-integrated learning by analyzing whether there is a statistically significant difference in students' mathematical communication skills between the experimental and control groups. Inferential statistical methods are employed for data analysis. Specifically, the independent samples t-test is utilized to test the research hypotheses and assess preliminary assumptions.

Before the independent sample t-test, a prerequisite test was conducted, namely data normality test analysis and data homogeneity test analysis. With the help of IMB SPSS 29, the results indicated that the data were normally distributed, with a significance value (sig) greater than 0.05 ($0.08 > 0.05$), and that the variances were equal, as evidenced by a significance value (sig) greater than 0.05 ($0.169 > 0.05$).

After passing the normality and homogeneity tests, an inferential analysis was conducted using an independent samples t-test on the posttest results of both classes: the experimental class and the control class. The analysis yielded the following data:

Tabel 6 Independent Samples Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | | |
|----------------|-----------------------------|---|------|------------------------------|--------|--------------|-------------|-----------------|-----------------------|---|----------|
| | | F | Sig. | t | df | Significance | | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | One-Sided p | Two-Sided p | | | Lower | Upper |
| Hasil Posttest | Equal variances assumed | 1.930 | .169 | -10.969 | 72 | <.001 | <.001 | -15.9298 | 1.4523 | -18.8249 | -13.0347 |
| | Equal variances not assumed | | | -11.024 | 70.830 | <.001 | <.001 | -15.9298 | 1.4451 | -18.8113 | -13.0483 |

Based on the results of the SPSS test above, because the significance value (sig) is less than alpha ($\alpha = 0.001 < 0.05$), it can conclude that there is a significant difference in the mathematical communication skills of PGMI students regarding the concept of integers between classes taught using technology-integrated learning and those taught using conventional methods.

After determining whether there is a difference between the experimental class and the control class, to find out whether the integration of technology in the learning design is effective or not, an independent sample effect size is used using IBM SPSS version 29.

Table 7 Independent sample effect size

| Information | Cohen's d Estimate Value |
|------------------|--------------------------|
| Posttest Results | 2,551 |

The result of the calculation of *the* effect size of technology integration in learning design to improve the mathematical communication skills of PGMI students obtained an effect size value of 2.551, meaning it is categorized as "very large". This shows that technology integration in learning design influences improving the mathematical communication skills of PGMI students in integers.

Based on the results of the effectiveness test and effect size test, it shows that the integration of technology in the learning design that has been carried out is effective and has a very large influence in improving the mathematical communication skills of PGMI students in integers.

Discussion

The results of the analysis regarding the implementation of learning with technology integration showed that it was achieved

both in terms of average and proportion. However, some students still faced challenges in solving integer problems, particularly when the questions were presented in narrative form and different from the examples provided, both in the experimental and control classes. One of the main obstacles in solving narrative problems is the difficulty of students in understanding the context of the problem presented through the story, identifying relationships between information, and linking the information to relevant mathematical concepts, while at the same time they were required to represent verbal information from the text into mathematical forms, such as diagrams, equations, or models, which are often a challenge in themselves. This also shows that students' mathematical communication skills in sub-integers have not yet developed well, when viewed within a period of one semester. In addition, seen from the learning factor, the improvement of the mathematical communication skills of PGMI students who apply learning with technology integration is still not optimal because in its implementation there are still several obstacles. For this reason, learning with technology integration needs to be developed more innovatively by considering the findings in this study.

Technology integration in mathematics learning is supported by the Cognitive Load Theory (Sweller, 1994) which states that the use of assistive devices such as technology can reduce cognitive load in processing complex information. Visualizations provided by applications or technological devices, such as interactive graphics or mathematical simulations, help students allocate more brain capacity to understand the core of the concept rather than processing separate elements. In the context of learning integers, technology can help

PGMI students understand the relationship between positive and negative concepts through intuitive visual representations, thereby accelerating conceptual understanding. Pedagogically, the use of technology is in line with the theory of Constructivism (Piaget & Barbel, 2008; Vygotsky, 1978), which emphasizes the importance of active and contextual learning. Technology allows students to explore concepts independently through simulations and interactive exercises, so that they can build conceptual understanding based on direct experience. In this process, technology also acts as a "scaffolding" or learning support, providing additional guidance such as direct feedback that accelerates concept mastery.

The results of the study described above indicate that students who engage in technology-integrated learning demonstrate greater improvement in mathematical communication skills compared to those who receive conventional instruction. This suggests that technology integration positively impacts the enhancement of students' mathematical communication abilities. Supporting this finding, research conducted by Sukmawati & Purbaningrum (2023) highlights the effectiveness of using Learning Management Systems (LMS) in blended learning environments to enhance students' mathematical communication skills. Similarly, Bahri (2020) and Nadlifah & Putri (2023) also found in his research that the use of e-learning in learning process can improve students mathematical communication skills. Therefore, technology-integrated learning is an effective approach for enhancing the mathematical communication skills of PGMI students, particularly in the context of integers

Implications of Research

Learning through effective technology integration can be applied to improve mathematical communication skills of PGMI students in integers. The implications of this study include the importance of emphasizing technology-integrated learning in teacher education curriculum design to improve basic mathematics skills, exploring innovative tools and methodologies to further develop mathematical communication skills and investigating the scalability of interventions in various educational contexts, and training educators in the effective use of technology in the classroom to maximize its impact on student learning outcomes.

Limitation

The limitations of this study include the concept raised only in the form of integers, the intervention was carried out in a limited time, so the long-term impact of technology cannot be measured, students who are not yet familiar with the Phet web menu, the use of media is limited to certain tools, without utilizing sophisticated technology such as AI or AR/VR, mathematical communication skills are only measured through written tests, without covering aspects of oral or collaborative communication.

CONCLUSION

Based on the results of the research and discussion in this study, the following conclusions were obtained: (1) the average mathematical communication ability of students using conventional learning was obtained for the posttest of 64.33 with a standard deviation of 5.63; (2) the average mathematical communication ability of students using learning with technology integration was

obtained for the posttest of 80.22 with a standard deviation of 6.77; (3) inferential statistical analysis obtained a value of significance is less than alpha ($0.001 < 0.05$), and it was concluded that there was a significant difference in students' mathematical communication skills using learning with technology integration. And the effect size results obtained were 2, 551 with a very large category. This means that learning with technology integration is effective in improving PGMI students' mathematical communication skills on the concept of integers.

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Exploring the Use of Mobile Technologies in Indonesian Mathematics Lectures

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Abstract

Despite extensive research on mathematics within universities, yet exploration of alternative solutions for challenges students faced during mathematics lectures was limited. Particularly, integrating mobile technology assistance via didactical design research received little attention. Therefore, researchers tried to describe the role of mobile technology in supporting mathematics lectures at an Indonesian university. Didactic design research was the method used in this research. Participants comprised 53 students aged 18–25 years. The main research tools included the researcher, a math comprehension test, an in-depth interview guide, and a hybrid mathematics module with mobile technology support. Thematic analysis uncovered learning barriers, while lecture data underwent qualitative and retrospective analysis. The findings were low mastery of prerequisites, carelessness, and a limited context for lecture. The hybrid module was able to minimize mathematics student learning obstacles in higher education. This research recommends lecturers facilitate problem-based activities with mobile technology to enhance students competencies in higher education.

Keywords: A hybrid mathematics module; mathematics lectures; mobile technology

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Abstrak

Cukup banyak penelitian yang mengkaji matematika di universitas, tetapi eksplorasi mengenai solusi alternatif terhadap tantangan yang dihadapi mahasiswa selama kuliah matematika masih terbatas. Khususnya, pengintegrasian teknologi seluler melalui penelitian desain didaktis kurang mendapat perhatian. Oleh karena itu, penelitian ini mencoba untuk mendeskripsikan peran teknologi seluler dalam mendukung kuliah matematika pada sebuah universitas di Indonesia. Didactical design research merupakan metode yang digunakan dalam penelitian ini. Partisipan terdiri dari 53 mahasiswa berusia 18–25 tahun. Instrumen utama adalah peneliti, tes pemahaman matematika, panduan wawancara mendalam, dan modul matematika hibrida dengan dukungan teknologi seluler. Analisis tematik digunakan untuk mengkaji hambatan belajar, sementara data perkuliahan dianalisis menggunakan kombinasi antara analisis kualitatif dan retrospektif. Temuan penelitian ini adalah penguasaan prasyarat yang rendah, kecerobohan, dan konteks perkuliahan yang terbatas. Modul hibrida mampu meminimalkan hambatan belajar mahasiswa matematika di pendidikan tinggi. Penelitian ini merekomendasikan kepada dosen untuk memfasilitasi kegiatan berbasis masalah dengan teknologi seluler untuk meningkatkan kompetensi mahasiswa di pendidikan tinggi.

INTRODUCTION

Previous theories and studies reveal that mathematics is a useful scientific discipline (Man-Keung, 2022; Yolcu & Popkewitz, 2019). However, mathematics remains a problem in learning, both in schools and universities (Gómez-Chacón, 2017; Lin et al., 2017). There is quite a lot of research examining mathematics in tertiary institutions (Silber & Cai, 2021; Zayyadi et al., 2019). However, not much still examines the learning barriers that students experience and the learning designs that can minimize these obstacles. This phenomenon is not only happening in Indonesia but also abroad. Here are some examples of studies that do not examine this phenomenon. Research in the city of Semarang, Indonesia (Muhtarom et al., 2020) has examined the beliefs of prospective mathematics teachers about solving mathematical problems. The research uses qualitative data analysis, revealing that while students exhibit constructivist beliefs during the problem-solving process, most prospective teachers hold spiritual beliefs about mathematical problems. This research at least provides an overview of one of the research trends in Indonesia.

More broadly, research in Chicago, USA (Jenifer et al., 2022) uses a quantitative approach to examine the relationship

between math anxiety and math avoidance by assessing learning strategies and student test scores in calculus courses. The results of the study have revealed several findings. First, the problem-solving strategy has been identified as the most difficult learning strategy. Second, anxiety about learning mathematics has been found to be related to unplanned involvement in problem-solving. Third, the avoidance of students in problem-solving efforts has been identified as partly mediating the relationship between math anxiety and exam performance. Research in Quebec, Canada (Hitt & Dufour, 2021) has examined students' cognitive problems when studying calculus, especially when solving open-ended problems. This research has used a quantitative approach with the type of teaching experiment. The results of this study have revealed that teamwork in learning has been driven by the reconstruction of representations and changes in perspective from divergent thinking related to students' understanding of situations to convergent thinking in providing solutions to problems.

If we analyze more deeply the findings from several previous studies, it becomes clear that these studies do not seem to integrate mobile technology to address the challenges faced by college students. This is noteworthy, considering that all students have smartphones that

could serve as valuable tools in their academic activities. Moreover, previous studies have not utilized didactic design research (DDR) as a method to solve research problems, even though DDR is particularly relevant for addressing issues in lectures. This is because DDR offers solutions grounded in the factors contributing to students' learning obstacles.

Based on the previous description, this study aims to find the factors leading to students' math learning challenges and outline the evolved math lecture designs addressing these obstacles. It also depicts their implementation, coupled with reflective insights. The right research design is didactical design research (DDR), which comes up with new ways to teach math by looking at what gets in the way of learning and how to use mobile technology (Cisonni *et al.*, 2023; Marfuah *et al.*, 2022; Ortega-Quevedo *et al.*, 2023). In this study, mobile technology refers to the use of devices such as smartphones in learning. Mobile technology is recommended because it can enhance learning independence and streamline learning activities from start to finish (Capinding, 2022; Ritonga *et al.*, 2024; Sopacua *et al.*, 2020). Moreover, it allows students to solve problems more easily by searching for information online using their smartphones (Bennett *et al.*, 2020). Additionally, all students possess smartphones and are proficient in operating them. Previous studies have also highlighted that mobile technology can optimize students' mathematical competence in higher education. This study uses a lecture design in the form of a hybrid module. From the previous research objectives, several questions are derived, including: (1.1) What is the description of the learning barriers that students experience in mathematics lectures? (1.2) What is the description of the hybrid mathematics lecture module with mobile technology assistance that is used

to minimize student learning barriers? (1.3) How is the description of implementing the hybrid mathematics lecture module with mobile technology assistance in class? (1.4) How is the revision of the hybrid mathematics lecture module with mobile technology assistance based on the implementation results in class? (1.5) After introducing the hybrid mathematics lecture module with mobile technology in class, how do the descriptions of learning barriers experience by students in math lectures change?

METHOD

The approach in this study was a qualitative approach to the type of DDR. DDR was chosen because this research aimed to develop alternative lectures to minimize learning barriers experienced by students (Prabowo *et al.*, 2022; Sukarma *et al.*, 2024). The alternative lectures intended in this study were didactic designs for mathematics courses for undergraduate students in agrotechnology and agricultural product technology at a tertiary institution in Mataram, Indonesia. The DDR paradigm was then relevant to the purpose of this study. DDR was based on an interpretive paradigm because it sought to make sense of the learning barriers that students experienced. In the context of this research, this paradigm was implemented by identifying the types of learning barriers that students experienced and the factors that resulted in these learning barriers. DDR was also based on a critical paradigm because it sought to provide alternative solutions in lectures. The practical design for math classes that used mobile technology to help students learn, created after looking at what got in the way of learning, was an example of this critical paradigm in action in this study (Suryadi, 2019b).

As previously described, this

research was conducted at a university in Mataram, Indonesia. The university was chosen because it was classified as one of the famous universities. However, some students needed help with mathematics-related lectures (results of FGDs with several mathematics lecturers). The target participants in this study were students of the Faculty of Agriculture. The faculty was chosen because it had a strict selection procedure for admitting new students. In addition, the faculty also made mathematics a compulsory subject in the curriculum. Using a purposive sampling technique, the participants in this study, originally intended to be 53 students, were narrowed down to 17 students (11 boys and six girls) from the agrotechnology and agricultural product technology study programs. This was because participants were naturally formed into class groups. The participants' ages ranged from 18 to 25 years. During high school, 5 participants majored in natural sciences, and 12 participants majored in social studies. Participants came from two ethnic groups: Sasak (12 students) and Sumbawa (5 students).

The main instrument in this research was the researcher because this research used a qualitative approach (Creswell & Creswell, 2018). Additional instruments in this research activity were a mathematics comprehension test, an in-depth interview guide, and a didactic design in the form of a hybrid module with mobile technology assistance for mathematics courses. This course was chosen because it was a mandatory basic subject and had many roles in the world of agriculture (McKim et al., 2017). The math comprehension test consisted of two math questions compiled by NCTM (NCTM, 2014). The in-depth interview guide used several semi-structured, open-ended questions. Open questions were used to obtain more in-depth information

according to the participant's point of view (Brown & Danaher, 2017). The compiled hybrid mathematics lecture module fulfilled the content validity test by 9 experts, namely 7 experts in the field of mathematics education and 2 education experts. Based on the assessment results of nine experts and after analyzing the CVR value (Lawshe, 1975), information was obtained that the CVR value for the mathematics module was 1. In other words, the hybrid module was essential for mathematics lectures. This study used the steps in DDR, namely prospective, metapedadidactic, and retrospective analysis (Marfuah et al., 2022), as shown in Figure 1 (See Appendix A).

In this study, triangulation of data sources was employed to strengthen trustworthiness (Morrison et al., 2019; Richard & Hemphill, 2018). NVivo-12 assisted in the thematic analysis of data pertaining to learning barriers (Sasidharan & Kareem, 2023). The thematic analysis involved familiarizing oneself with the data, finding the initial code, determining themes, reviewing themes, and naming or defining themes (Pigden & Jegede, 2019). A combination of qualitative data analysis and retrospective analysis was also used to look at the outcomes of introducing a mobile technology-based math lecture module (Miles et al., 2014; Suryadi, 2019b).

Qualitative data analysis entailed reducing data, presenting data, and drawing conclusions (Miles et al., 2014). During the data reduction phase, researchers sorted the necessary data by eliminating some less important data for analysis. Subsequently, researchers analyzed the data by assessing the coherence, flexibility, and unity of the didactic situation in the mathematics lecture module (Suryadi, 2019a). Data from the analysis were presented in various forms, such as descriptions, tables, and illustrative images.

Following that, the researcher concluded by revising the mathematics lecture module based on the results of the previous analysis.

RESULTS AND DISCUSSION

Results

What is the description of the learning barriers that students experience in mathematics lectures?

Based on the results of the NVivo-12-assisted thematic analysis, data was collected on the theme of student learning barriers in math classes, as shown in Table 1 (See Appendix B). After the themes were formed, this study attempted to determine the factors that caused students to experience learning difficulties by conducting in-depth interviews with several students. Concerning T_a, information was obtained from in-depth interviews that indicated that students did not understand the meaning of the questions because they rarely got questions in the form of stories during mathematics

learning at school. Regarding T_b, information was obtained that students did not experience learning difficulties. It is because, during in-depth interviews, students can answer according to what is on the answer sheet. The presence of T_d, which confirms the low ability to understand students' pre-requisite material, and the presence of T_c, which confirms that students are not careful in doing their work, can be seen in Table 2. Interview excerpts for the T_c theme can be seen in Table 2 (See Appendix B).

What is the description of the hybrid mathematics lecture module with mobile technology assistance that is used to minimize student learning barriers?

After analyzing the types of student learning barriers, the next activity carried out in this study was the compilation of a hybrid mathematics lecture module. The module was prepared based on the results of the analysis of student learning barriers that were described in the previous section. The alternative solutions offered in the

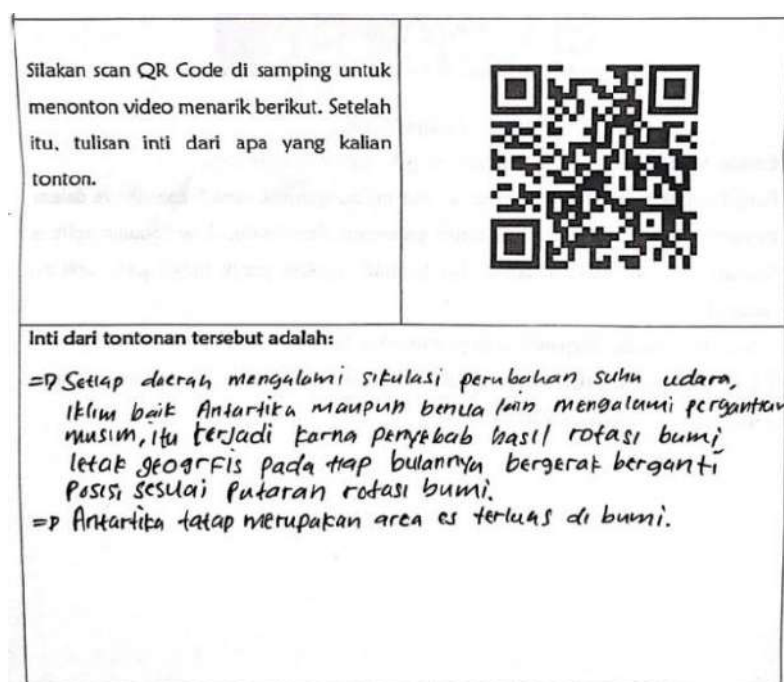


Figure 3. A snippet of Student Answers for Let's Watch Activities

hybrid mathematics learning module based on analyzing learning barriers can be seen in Table 3. Based on the considerations in Table 3, a mathematics lecture module that integrated these alternatives was developed. Because what was compiled in this study were modules, several activities were added to form a complete learning experience. For more detailed information regarding the hybrid mathematics lecture module, it could be accessed at the following link: <https://shorturl.at/nvo69>. A complete description of alternative solutions offered by researchers can be seen in Table 3 (See Appendix B).

In addition, the hybrid mathematics lecture module integrated ICT into learning. It combined the use of ICT with presenting the results of working on activities in print. There were several forms of integrating ICT in the module, such as the use of the QR code as a basis for learning activities, the use of online test applications to ensure students understood the prerequisite material, the use of the internet to search for information and find solutions to the problems presented, the use of *Android-based GeoGebra* in the learning process, as well as the use of smartphones as the main tool in carrying out learning.

How is the description of implementing the hybrid mathematics lecture module with mobile technology assistance in class?

In the early lecture activities, as usual, the lecturer opened the class with a greeting and an opening prayer. After that, students listened to the lecturer's explanation regarding the purpose of the lecture. Namely, students were expected to be able to describe functions consisting of one or two independent variables and solve agricultural problems involving equations of linear functions. Students were then asked to complete the *Let's*

Play activity by scanning the QR code in the hybrid mathematics lecture module. Snippets of student answer reports for this activity can be seen in Figure 2. Figure 2 also showed that some students did not understand the prerequisite material. However, after being confirmed with students, information was obtained that they experienced problems with the internet connection when playing, so they could not work on the questions properly.

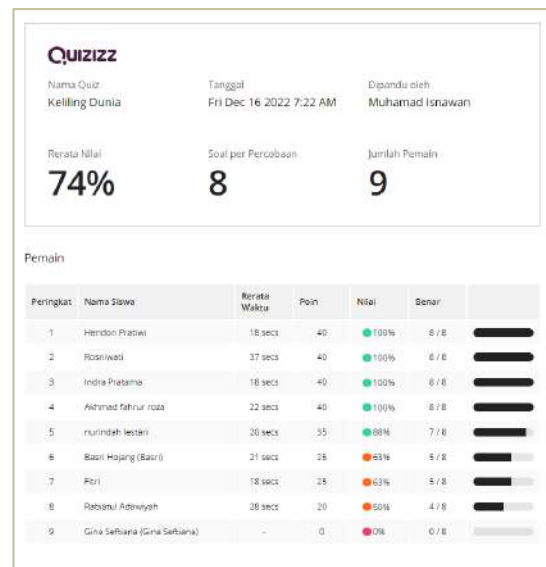


Figure 2. Snippets of Student Answer Reports for *Let's Play* Activities

In addition, in this activity, there were several obstacles that the researcher found. First, implementing online tests via *Quizizz* required lecturers to be in an online condition, so they required lecturers to also activate *Quizizz* when students were carrying out tests. This automatically made learning less flexible because it had to be done under the guidance of a lecturer. Second, students who experienced internet connection problems could not take or continue the test. Next, students worked on *Let's Watch* activities. In this activity, students were asked to watch videos related to Antarctic conditions, according to NASA. The video was expected to arouse students' interest and

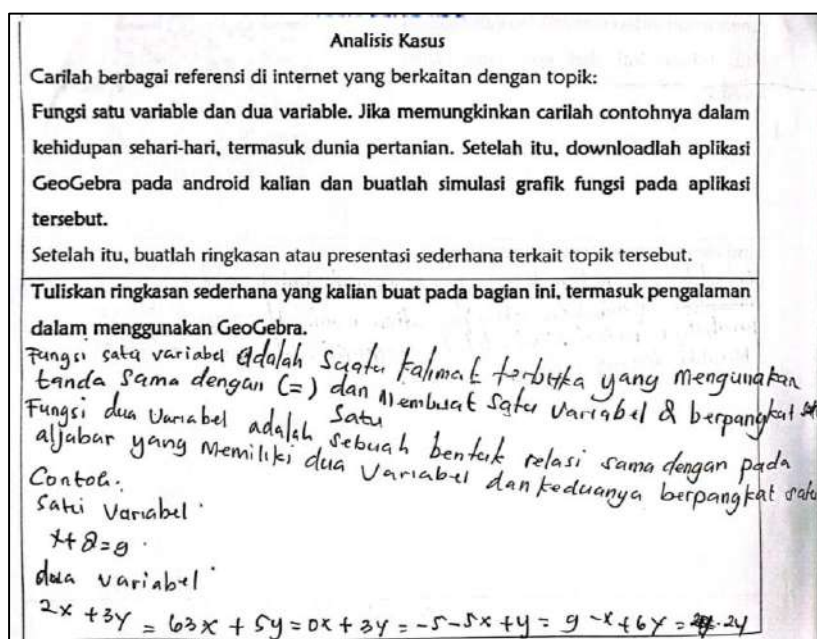


Figure 4. Snippets of Student Answers for Let's Discover Activities

motivation to start lectures and inspire them to realize the uniqueness of Antarctica from a mathematical point of view. Figure 3 shows snippets of student answers for the *Let's Watch* activity. In essence, students in this activity could do the activity very well. There was one obstacle to this activity, such as the fact that the time used by students tended to be more than allocated because there was no limit to the answers students could give.

The lecture activities were then continued with *Let's Discover* activities. In this activity, students used smartphones to find as much information as possible via the internet to solve problems presented in the hybrid mathematics lecture module. Figure 4 provides examples of student answers in the *Let's Discover* activity. Students were able to do this activity well. Students were able to install *GeoGebra* on their respective smartphones and simulate graphing functions on the application. Based on the results of observations during lectures, collaboration between group members and complete information on the internet helped the students solve the problems well. A snippet of student answers for this activity can be

seen in Figure 4.

There were several obstacles experienced by students in *Let's Discover* activities, such as students not dividing tasks when looking for information so that work results were less effective and efficient; the information obtained by students tended to be conceptual yet, so lecturers had to give them reinforcement; and students did not know how to make graphic simulations on *GeoGebra*. However, the main obstacle to this activity was the allocation of learning time, which tended to be mostly spent on this activity. The next activity was *Let's Present*. In this activity, there was a discussion between groups of students when presenting their work. Each group responded to the other groups. Although there were also some obstacles experienced in this activity, such as several groups having difficulty determining group presenters, the responses from one group to another group still did not lead to a conceptual conclusion. In addition, pointing fingers between group members as presenters tended to occur during presentation activities. Documentation of this activity can be seen in Figure 5.



Figure 5. Snippets of Student Answers for Let's Present Activities

After each group presented their work results, students concluded the

concept of the function of one and two variables and the benefits of functions in everyday life. Figure 6 provides information on student answers in the *Let's Summarize* activity. In this activity, the main obstacle was that students seemed unable to correctly conclude the function of one and two variables. Therefore, the lecturer validated it by saying that a *variable y* is a function of the *variable x* if x and y have certain rules that state the relationship between x and y so that for each x value, it is possible to have a y value.

The next activity was *Let's Institutionalize*. In this activity, students were asked to summarize an article containing a linear function consisting of several variables. Unfortunately, students in this activity might not have done it optimally. This was due to the time allocation, which tended to be considered insufficient. A snippet of student answers can be seen in Figure 7.

Finally, students conducted reflection activities on the concepts obtained and the learning process. Students in this section revealed that they felt happy learning in this lecture and looked wrong

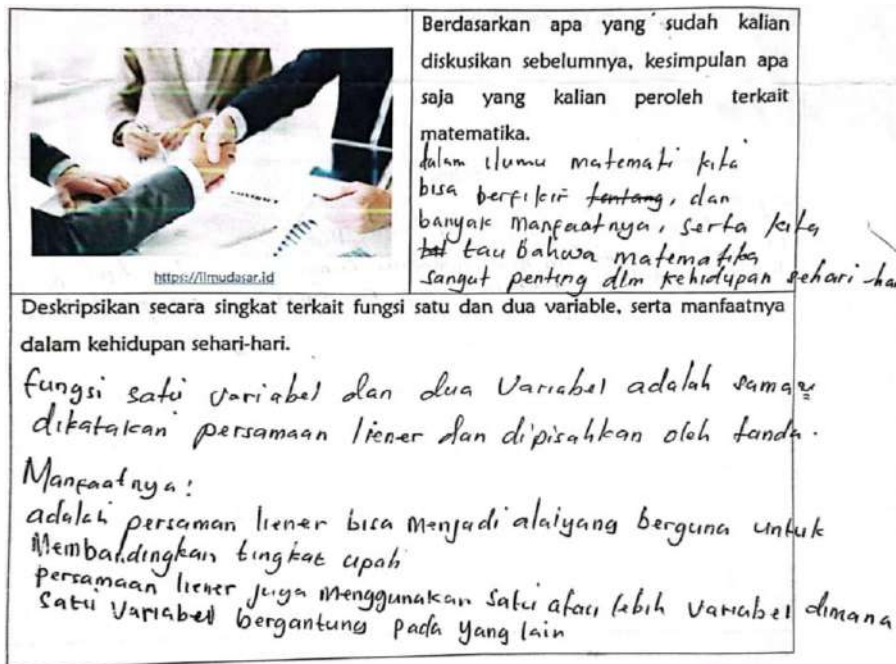


Figure 6. A Snippet of Student Answers for Let's Summarize Activities

in expressing appropriate concepts. The lecturer then confirmed the students' answers, and the students revised their previous answers. Researchers learned crucial information from this activity, namely that students responded favorably to the hybrid mathematics lecture module's teaching methods. According to some students, the lectures seemed different from other lectures, students became happier and more motivated during lectures, and students considered that the discovery of basic concepts was important to emphasize during module work. Figure 8 provides snippets of student answers in the *Let's Reflect* activity.

| Pertanyaan | Respon |
|--|--|
| Bagaimanakah perasaan kalian mengikuti kegiatan pembelajaran pada hari ini? | <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>  |
| Fungsi linier merupakan salah satu konsep yang melibatkan persamaan linear yang tidak bermanfaat dalam bidang pertanian. | Benar/Salah. |

Figure 8. A Snippet of Student Answers for *Let's Reflect* Activities

How is the revision of the hybrid mathematics lecture module with mobile technology assistance based on the implementation results in class?

Based on the description in the previous section, students experienced several obstacles during learning activities. *Let's Play* activities required lecturers to be

online when working on test questions, internet connections were sometimes problematic, time allocations tended to be more than they should be, there were no character limits for student answers for each activity, students were less able to divide assignments when searching for information on the internet, the information provided by students was not conceptual, they did not know how to make graphical simulations on *GeoGebra*, students were still confused in determining the presenter of the results of group work, the responses given by students were still general, the conclusions given by students were still general, student answers for *Let's Institutionalize* activities were still general, and certain QR codes did not access the right file.

Based on these constraints, there were several revisions to the hybrid mathematics lecture module. This revision was expected to be an alternative solution for the next lecture. It could train educators so that they did not feel that the learning design was perfect enough that it did not require future improvements. These revisions can be seen in Table 4.

After introducing the hybrid mathematics lecture module with mobile technology in class, how do the descriptions of learning barriers experienced by students in math lectures change?


| Masalah | |
|---|--|
| Buatlah ringkasan terkait fungsi linier dari bacaan yang ada pada QR code di bawah. |  |
| Solusi Masalah | |
| <p>Setiap musim diladang atau lahan pertanian rata-rata menghitun menggunakan fungsi linier, dan setiap musim memiliki kenaikan setiap pendapatan atau per fahun.</p> | |

Figure 7. A Snippet of Student Answers for *Let's Institutionalize* Activities

Based on the description of the obstacles during implementation, it can be concluded that students were not indicated to experience learning obstacles such as those described in the second question, as explained in the previous point (the first research question). This was because during the implementation, the students were able to answer the questions according to what the researcher expected. In addition, students appeared to be more careful when solving problems, even though time constraints still prevented them from doing so. However, the design was what caused this issue. The instructions in the design were less operational, so it directed students to work without character limits and resulted in excessive time allocation. In other words, one form of obstacle that students experienced tended to be technical or instrumental matters during lectures.

Table 4. Revision of the Hybrid Mathematics Lecture Module

| Experienced Obstacles | Design revision |
|--|---|
| <i>Let's Play</i> activities require lecturers to work online on test questions. | There are no revisions to the module. Lecturers in this activity are expected to ensure that the online test application is ready before learning begins. |
| An Internet connection sometimes has problems. | There are no revisions to the module. Lecturers make sure students have their own data plan that will be used when encountering internet connection problems on wifi. |
| Time allocation tends to be more than it should be. There is no character limit for student answers for each activity. | Limit the number of answer characters or the number of student paragraphs for each activity. |
| Students are not sure how to use <i>GeoGebra</i> to simulate a graph. | |
| Students are less able to divide tasks | In the <i>Let's Discover</i> activity, the researcher added instructions to the module by |

| Experienced Obstacles | Design revision |
|---|--|
| when searching for online information. | "dividing tasks in finding information on the internet when solving problems, including presenters." |
| The information provided by students is not yet conceptual. | Added guide editor to the module by "focus on searching using keywords that match the problem" and added scaffolding to the Come on Find activity. |
| Students are still confused in determining the presenter of the group work results. | In the <i>Let's Present</i> activity, the researcher added instructions to the module by "choose one of the group members as the presenter." |
| The responses given by students are still general. | Added redaction instructions to the Come on Presents activity with a "focus on providing responses related to the problem being solved." |
| The conclusions given by students are still general. The students' answers for the <i>Let's Institutionalize</i> activity were still general. | Adding trigger questions so that student answers become more focused. |
| Certain QR code is not accessing the right file. | Provides document links in modules. |

Discussion

What is the description of the learning barriers that students experience in mathematics lectures?

If it is associated with theories related to the types of learning barriers (Brousseau, 2002; Prabowo et al., 2022), then students experience learning barriers with ontogenic obstacles that are psychological (not careful in doing) and conceptual (lack of mastery of the prerequisite material). Not being careful in working on the context of this study refers to students tending to be in a hurry when working on it. This action then causes the student's answer to be wrong. This action also occurs not just once but several times, thus

requiring special intervention in lectures. If allowed to drag on, it impacts student learning outcomes that are not optimal. What's more, if the questions that students must solve are multiple-choice, it indicates that students who experience learning difficulties will not find the right answer. When what is done is a description question, it affects the student's answer in the next step. The illustration is that when students are not careful when writing down questions to be answered, all student answers will automatically be wrong. This study's results align with the theory and several previous studies that reveal that students' carelessness negatively impacts mathematics learning outcomes (Isnawan, 2022; Makonye & Khanyile, 2015).

Furthermore, students' lack of understanding regarding prerequisite material is a problem often found in the context of lectures. One of the properties of mathematics is procedural. In other words, when someone does not master the previous concept (prerequisite material) in mathematics well, they are likely less able to master the next concept that requires the prerequisite material (Deeken et al., 2020). The results of this study are in line with this theory and with several previous studies that revealed that students' common knowledge of prerequisite material is one of the obstacles experienced in learning mathematics (Hasibuan et al., 2018; Makhubele, 2021).

If it is related to the theory of learning barriers (Brousseau, 2002; Prabowo et al., 2022; Puspita et al., 2023), information is obtained that students are indicated to experience learning barriers with this type of epistemological obstacle because when learning about rational numbers in schools, mathematics teachers in schools use limited contexts and rarely use illustrative models. This, in turn, impacts the lack of students' collaboration skills

during lectures. This type of learning barrier is a learning obstacle that is important enough to get the attention of educators or researchers in mathematics education. This is because epistemological obstacles are obstacles that directly affect the processes that occur in learning (Elias et al., 2018).

A student may have a negative interest or attitude toward mathematics because of this learning barrier. In addition, mathematics, which is *a priori* (Palmquist, 1987), also forces learning barriers of this type not to appear in the learning context. This is because mathematics studied anomalies and the mathematical nature of *a priori* knowledge as if it were a *posteriori* knowledge (Palmquist, 1987). This posterior form then forces mathematics to begin to be studied by presenting problems in everyday life or operational problems to achieve *a priori* mathematics. The results of this study are also in line with several previous theories and studies that reveal that epistemological obstruction is one of the dominant types of learning barriers that cause students to experience obstacles in learning mathematics (Isnawan, 2022; Prabowo et al., 2022). Having identified the barriers students face in mathematics lectures, the next section examines how the hybrid module was designed to address these challenges.

What is the description of the hybrid mathematics lecture module with mobile technology assistance that is used to minimize student learning barriers?

The hybrid module is an alternative solution (Lumbantoruan & Ditasona, 2024) because, based on several theories and the results of previous research, it is concluded that learning that combines ICT with manual work will positively impact the quality of learning and student competence (Ammy & Maryanti, 2023;

Dockendorff & Solar, 2018; Fathiyyah Firdaus & Marina Angraini, 2023; Tossavainen & Faarinen, 2019). There are several reasons for using ICT in the module, such as all students having smartphones that can be connected to the internet, QR codes tend to be effective and efficient in accommodating activities in learning, and online test applications arouse student interest and motivation in learning (Bennett et al., 2020; Santagata et al., 2021; Tomar et al., 2024; Tossavainen & Faarinen, 2019). The application challenges students to compete with other students in learning activities.

Apart from that, the hybrid mathematics lecture module is structured based on didactic situation theory. This theory divides learning activities into action situations, formulation, validation, and institutionalization (Brousseau, 2002; Suryadi, 2019a). In action and formulation situations, students are asked to solve problems using all the information available on the internet. After the problem is solved, students enter a validation situation, namely, a situation where they present the results obtained with the aim of validating the answers they have. After the answers are validated, students enter an institutionalization situation, namely a situation where they use the concepts, they have discovered to solve other problems presented in the module (Suryadi, 2019b). This kind of learning pattern can then be called an epistemic lecture pattern because it is able to facilitate students in constructing concepts based on physical and mental activities during lectures (Isnawan, 2022; Sukarma et al., 2024). Ultimately, these activities aim to reduce students' learning barriers, allowing their mathematical competence and collaboration skills to develop optimally. To demonstrate this, the next section explains the implementation of the hybrid mathematics module.

How is the description of implementing the hybrid mathematics lecture module with mobile technology assistance in class?

Based on the research results described previously, it is known that several responses are given by students during the implementation of the hybrid mathematics lecture module. Figure 2 shows that most students can know the prerequisite material well so that lectures can be continued in the next activity. These results are based on theory and previous research revealing that learning activities can be continued when students understand the prerequisite material is sufficient (Hasi-buan et al., 2018; Makhubele, 2021). Figure 2 also shows that some students do not understand the prerequisite material. However, after being confirmed with students, information is obtained that they experience problems with the internet connection when playing, so they cannot work on the questions properly.

During the *Let's Play* activity, students experience technical problems while answering test questions. This result also aligns with (Isnawan, 2022), which reveals a tendency for students to experience technical problems during learning that hinder the learning process itself. There is one obstacle to the *Let's Watch* activity, such as the fact that the time used by students tends to be more than allocated because there is no limit to the answers students can give. This study's results align with the theory and several previous studies that reveal that student-centered learning tends to take longer than it should (Bremner et al., 2022; Emaliana, 2017). Based on the results of observations during *Let's Discover* activities, collaboration between group members and complete information on the internet make the problems solved by students quite well. These results are in line with theory and some previous research, which

reveals that social interaction in groups would help students solve a problem, and the use of ICT would make it easier for students to obtain information or strategies needed to solve problems (Topciu & Myftiu, 2015; Tossavainen & Faarinen, 2019).

Furthermore, in the *Let's Present* activity, there are some obstacles experienced, such as several groups having difficulty determining group presenters, and the responses from one group to another group still do not lead to a conceptual conclusion. This study's results align with the theory and several previous studies, which reveal that in discussion activities, not all students can provide good responses (Ahmad, 2021; Sjöblom et al., 2022). In addition, pointing fingers between group members as presenters tends to occur during presentation activities. Students tend to lack confidence in learning activities (Ahmad, 2021). Like the previous activity, in the *Let's Summarize* activity, the main obstacle is that students seem unable to correctly conclude the function of one and two variables. Therefore, the lecturer validates it by saying that a variable y is a function of the variable x if x and y have certain rules that state the relationship between x and y so that for each x value, it is possible to have a y value. It is important to note that during the validation phase, the lecturer must provide directed feedback carefully. This ensures that the concepts developed by students reach the scholarly knowledge stage. This study's results align with the theory and several previous studies, which reveal that educators have a very important role in providing conclusions when students tend to be less than optimal or not completely correct in concluding the concepts found (Koskinen & Pitkäniemi, 2022; Lodge et al., 2018).

The next activity is *Let's Institutionalize*. In this activity, students cannot do it

optimally. This is due to the time allocation, which tends to be considered insufficient. These results align with theory and previous studies, which reveal that students tend to be less able to implement concepts obtained in learning in contexts, situations, and conditions that are different from before, especially when it involves problems of everyday life (Hartmann et al., 2021; Pongsakdi et al., 2020). The last activity is my reflection. Students in this section reveal that they feel happy learning in this lecture. The results of this study are in line with the theory and several previous studies that reveal that student-centered learning and using ICT tend to get positive responses during learning activities (Dockendorff & Solar, 2018; Tossavainen & Faarinen, 2019).

How is the revision of the hybrid mathematics lecture module with mobile technology assistance based on the implementation results in class?

As previously described, there were several obstacles experienced during lectures. This revision is expected to be an alternative solution for the next lecture. It can train educators so that they do not feel that the learning design is perfect enough that it does not require future improvements. Ideally, reflecting on learning activities is mandatory for educators to carry out during learning (Muchlis et al., 2020). If possible, three types of reflection will be conducted: reflection on learning, reflection during learning, and reflection on learning (Ghorbanpour et al., 2021). The results of this research are then in line with several previous studies (Fitriati et al., 2023; Joubert et al., 2020), which revealed that redesigning learning designs through reflection activities is a necessity for educators so that the quality of learning in the future will be better.

After introducing the hybrid mathematics lecture module with mobile technology in class, how do the descriptions of learning barriers experienced by students in math lectures change?

As described in the research results section, students indicate that they do not experience learning obstacles as in *Research Question 1*. However, students indicate that they experience obstacles with the instrumental ontogenic obstacle type because there are several instructions that are lacking in the learning design so that the answers that students give are less than optimal and this results in excessive learning time. Yet, according to several previous theories and research (Capinding, 2022; Sopacua et al., 2020), instructions in modules play a crucial role in enabling students to learn independently when using learning modules. When related to the theory of learning obstacles (Brousseau, 2002; Prabowo et al., 2022), students are indicated to be experiencing instrumental ontogenic obstacles after the implementation of the hybrid mathematics lecture module with mobile technology assistance. This is due to the presence of incomplete instructions in the module. This research aligns with several previous theories and studies (Isnawan, 2022; Marfuah et al., 2022) that revealed instrumental ontogenic obstacles as one of the common types of obstacles that arise, especially when analyzing teaching materials or instructional design. This is because there is no perfect design in education.

Implication of Research

This research recommends that math educators integrate ICT tools into instruction. Online tests add depth, videos boost motivation, QR codes streamline, and problem-based learning enriches

dynamics. The future study invites researchers to explore intricate didactic interplay, spotlighting validation and institutionalization phases for future inquiries. In addition to mathematics educators in higher education, the results of this study are also expected to be applicable to other STEM disciplines. This aims to evaluate the broader impact of the hybrid module on improving learning outcomes.

Limitation

This research had several limitations. First, the researcher did not prepare a laptop that was on standby for the *Let's Play* activity before the lecture. Second, the researcher did not prepare equipment that would help students in making presentations, such as cardboard and colored markers that students could use in carrying out the *Let's Discover* activity. In addition, this study was conducted in a single institutional context, which limited the generalizability of the findings to other cultural or educational settings.

CONCLUSION

Based on findings, there are some conclusions of this research. Students presently grapple with math learning obstacles ranging from inattentiveness to methodological nuances (psychological ontogenic) to struggling with core concepts, especially rational number operations (conceptual ontogenic). Contextual constraints and illustrative models further impede mathematics progress (epistemological hurdle). A hybrid math module, combined with mobile technology, features interesting, sequenced activities. Mobile technology (online tests, educational videos, and QR codes) inject innovation. Activities align with learning stages, weaving didactic scenarios for holistic understanding. Most activities

function well, with ongoing refinements based on implementation outcomes. The hybrid module addresses ontogenic obstacles but introduces didactic challenges due to unclear scaffoldings. Students battle understanding and applying new math concepts in problems, traced back to inadequate validation. This affects institutionalization phase. The study advocates systematic didactic phases. In short, the hybrid mathematics lecture module can minimize learning obstacles that students experience during lectures. The hybrid mathematics lecture module is then included in the epistemic learning pattern because it can construct knowledge through various mental and physical activities.

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Appendix A of article entitled Exploring the Use of Mobile Technologies in Indonesian Mathematics Lectures

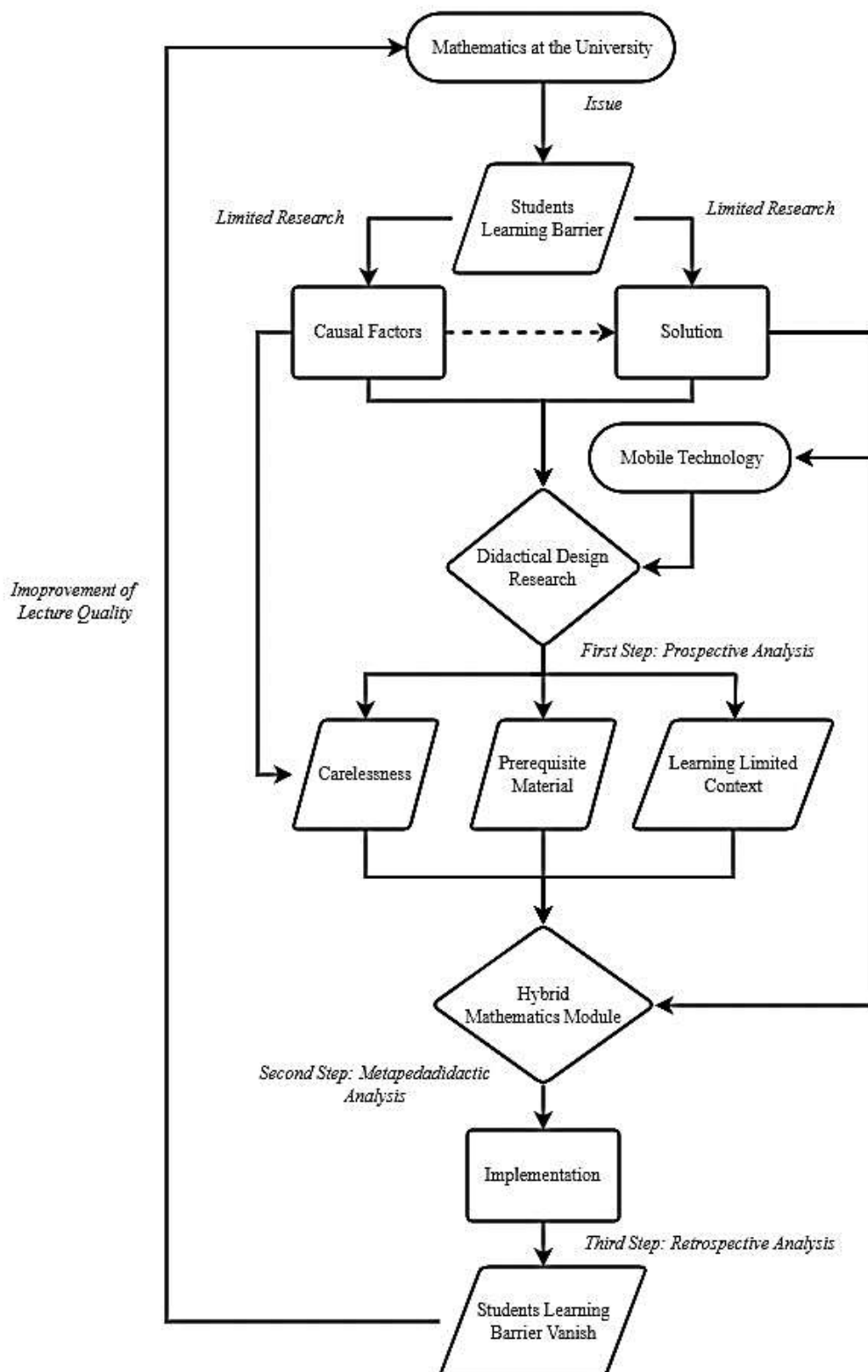


Figure 1. Research Procedure

Appendix B of article entitled Exploring the Use of Mobile Technologies in Indonesian Mathematics Lectures

Table 1. Student Learning Barriers Theme

| Initial Code | Theme | References |
|--|---|------------|
| Students are less able to make mathematical modeling (subtraction). Students have a lower ability to perform mathematical modeling (division). Students are less capable of developing mathematical models (addition). Students have a lower ability to perform mathematical modeling (percentage). Students face no difficulties. | T_a (student made a mistake in making a mathematical model). | 9 |
| Students are less able to add rational numbers. Students have a lower ability to multiply rational numbers. Students make mistakes when operating with integers. | T_b (Students face no difficulties). T_c (students are wrong in operating numbers). | 7 5 |
| Students are wrong in determining the number equivalent to certain rational numbers. Students make a mistake when converting rational numbers to decimal form. Students skip several steps of the process. | T_d (student wrong in equating rational numbers). T_e (students are not careful in doing). | 4 1 |

Table 2. Snippets of In-depth Interviews with Several T_c Students

| Researcher Questions | Participant Answers |
|--|--|
| <i>Did you notice your mistake when operating on numbers for this section?</i> | <i>P1: Wrong sir.</i> |
| <i>Where is the error?</i> | <i>P2: I realize it.</i> |
| <i>What is the reason you realize it now?</i> | <i>P1: I used the rational number multiplication method, which is not right.</i> |
| <i>What about the equivalence of rational numbers?</i> | <i>P2: I should have multiplied the quantifier and denominator.</i> |

Table 3. Alternative Solutions Offered in the Hybrid Mathematics Lecture Module

| Learning Barriers | Alternative Solutions |
|--|--|
| Students are not careful in doing this. | Add instructions as reminders for students to do activities in the module carefully, pay attention to the time allocation for the work, and ask students to check their answers before presenting or submitting. |
| Students do not master the prerequisite material. | Several questions are given to students during the early lecture activities to ensure mastery of the prerequisite material. |
| There are limitations to the context that educators use. | Present various contexts in the form of problems that students must solve and utilize ICT to solve the problems presented. |



Interrelationship of Mathematical Problem-Solving Ability, Mathematical Disposition, and Gender among Grade 10 Students

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Abstracts

Although numerous studies have examined mathematical disposition (MD) and mathematical problem-solving (MPS) ability, a significant gap remains in understanding their interaction with gender differences. This study aimed to analyze the effect of MD on MPS, investigate gender-based differences, and identify the most influential MD indicators. Conducted in South Sulawesi, Indonesia, this research involved 300 tenth-grade students using an ex-post facto quantitative design. The instruments comprised a mathematical problem-solving test and a mathematical disposition questionnaire. Data were analyzed using descriptive and inferential statistics. The findings indicated that 77.6% of students were classified as having low MD, while 71.0% exhibited similarly low levels of MPS. MD significantly affected MPS (59.5%), with the indicator 'appreciation of the value of mathematics' making the largest contribution (0.293). Significant gender differences emerged in MD, whereas no such differences were observed in MPS. These findings highlight the importance of innovative and differentiated teaching strategies that prioritize improving students' MD. Such strategies are essential for fostering inclusive, responsive, and equity-oriented mathematics education, a commitment that educators and policymakers should actively strive to uphold.

Keywords: Mathematics disposition, Mathematics problem solving, Gender; Mathematics Disposition Indicators

Information of Article

| | |
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Abstrak

Meskipun banyak penelitian telah mengeksplorasi disposisi matematis (DM) dan kemampuan pemecahan masalah matematika (MPS), kesenjangan signifikan masih ada dalam memahami interaksinya dengan perbedaan gender. Penelitian ini bertujuan untuk menganalisis pengaruh DM terhadap MPS, mengeksplorasi perbedaan berdasarkan gender, serta mengidentifikasi indikator DM yang paling berpengaruh. Penelitian ini melibatkan 300 siswa kelas sepuluh di Sulawesi Selatan, Indonesia, dengan desain kuantitatif *ex-post facto*. Instrumen penelitian meliputi tes kemampuan pemecahan masalah matematika dan angket disposisi matematis. Data dianalisis menggunakan statistik deskriptif dan inferensial. Hasil menunjukkan 77.6% siswa berada dalam kategori rendah pada DM, sementara 71.0% menunjukkan tingkat MPS yang serupa. DM memberikan kontribusi signifikan terhadap MPS (59.5%), dengan indikator 'apresiasi terhadap nilai matematika' memberikan kontribusi terbesar (0.293). Terdapat perbedaan signifikan pada DM berdasarkan gender, namun tidak pada MPS. Temuan ini menyiratkan pentingnya strategi pengajaran yang inovatif dan berbeda yang memprioritaskan peningkatan MD siswa. Strategi semacam itu sangat penting untuk mendorong pendidikan matematika yang inklusif, responsif, dan berorientasi pada kesetaraan, sebuah komitmen yang harus ditegakkan oleh para pendidik dan pembuat kebijakan secara aktif.

INTRODUCTION

Imagine a world without mathematical problem-solving. It's a fundamental aspect of the teaching and learning process in mathematics, requiring *the application* of mathematical concepts to find solutions (Nalurita et al., 2019). These problems can be classified into two categories: routine problems, which can be solved using procedures or steps previously learned, and non-routine problems, which demand new strategies as they cannot be solved using known methods (Mairing, 2020)

The Mathematical Problem-Solving Ability (MPSA) is a crucial concept in mathematics education. It refers to an individual's capacity to apply mathematical knowledge, skills, and understanding to solve problems in unfamiliar contexts (Kantowski, 1977; Liljedahl et al., 2016; Firmansyah & Syarifah, 2023). Pólya & Szegő, (1945) introduced a four-stage MPSA framework: understanding the problem, devising a plan, implementing the plan, and reflecting. This framework, further developed by Schoenfeld (1985), underscores the role of metacognition in MPSA. Metacognition, the awareness and understanding of one's own thought processes, is a crucial element that enhances learning and understanding in mathematical problem-solving.

MPSA is a crucial skill for students as it fosters the development of critical and analytical thinking, which is essential for solving complex problems across various life and work domains. For instance, in a professional setting, MPSA can be used to analyze data and make informed decisions. Additionally, MPSA enhances the ability to adapt to changes and challenges in a dynamic global environment while equipping students with the necessary skills to thrive in careers within the digital era and knowledge-based economy (Okolie et al., 2021). The importance of this ability is increasingly emphasized by the need for students to face the ever-changing challenges of the future.

However, several studies indicate that students' MPSA remains relatively low, and this is a matter of urgent concern. The 2022 Programme for International Student Assessment (PISA) results placed Indonesia at rank 68 with a mathematics score of 379. Tampa et al. (2022) found that the MPSA of 8th-grade junior high school students needed to be higher, regardless of the school's status or accreditation level. The Trends in International Mathematics and Science Study (TIMSS) survey also reported that the average mathematics score of Indonesian students was below the international average (TIMSS, 2019). Other studies have shown that low MPSA is found across all

levels and stages of education (Gunawan *et al.*, 2023).

One significant factor influencing students' MPSA is Mathematical Disposition (MD). Katz (2009), Yani and Ningsih (2019), and Atallah *et al.* (2010) stated that MD is closely related to attitudes, beliefs, and tendencies that encourage positive thinking and effort in learning mathematics. Meanwhile, Royster *et al.* (1999), Depi *et al.* (2022), and Fairus *et al.* (2023) described MD as deliberate actions frequently performed during mathematics learning. (NCTM, 2000, 2014; Biber *et al.*, 2013) expanded MD into seven key indicators: self-efficacy, flexibility of thinking, persistence, curiosity, metacognition, mathematical connections, and appreciation of mathematical values. These seven indicators work complementarily to support the development of students' MPSA.

Self-efficacy in mathematics enables students to believe in their ability to complete tasks, making them more persistent even when faced with difficulties. Research indicates self-efficacy strongly correlates with MPSA (Zakariya, 2022; Chytrý *et al.*, 2020). Flexibility of thinking allows students to select the best approach for solving problems based on specific contexts, which has also been proven to enhance MPSA (Magalhães *et al.*, 2020; de Santana *et al.*, 2022).

Persistent students strive to understand problems, try different approaches, and correct errors. This perseverance is crucial for solving complex mathematical problems (Xiao & Sun, 2021; Scherer & Gustafsson, 2015). Furthermore, curiosity drives students to explore new ideas and discover creative solutions to problems (Peterson & Cohen, 2019; Jaen & Baccay, 2016).

Mathematical connections and appreciation of mathematical values also play a significant role. Students who can link mathematical concepts to real-life

situations better understand the relevance of their knowledge (Artstein *et al.*, 2014; Jawad, 2022). Meanwhile, an appreciation of mathematical values motivates students to comprehend and apply mathematical concepts in practical contexts (Chen *et al.*, 2018; Hutajulu *et al.*, 2019).

Previous studies on the relationship between mathematical disposition and Mathematical Problem Solving Ability (MPSA) have been conducted by many experts. Jacobbe *et al.* (2012) and Hoon *et al.* (2021) found that mathematical disposition has a significant influence on MPSA and on increasing engagement in mathematics learning. Gökçe & Güner (2024), revealed that students with good mathematical disposition are more actively engaged in exploratory learning and are better prepared for challenging mathematical tasks. However, these studies only highlighted the global relationship between mathematical disposition and MPSA, without examining the specific contribution of each mathematical disposition indicator, such as self-efficacy, flexibility of thinking, perseverance, and others to MPSA. It is important to address this gap because each mathematical disposition indicator has a different role in supporting MPSA. Understanding the specific contribution of each indicator is crucial as it will provide more targeted guidance for educators, allowing them to strengthen those aspects of mathematical disposition that need extra attention. To fill this literature gap, one of the objectives of this study is to explore the contribution of each mathematical disposition indicator to students' MPSA.

In addition, gender differences in mathematics education have long been a focus of research (Barrow-Green *et al.*, 2019). Differences in cognitive, psychological and learning style preferences between males and females influence how they process information and solve

mathematical problems (Mašić et al., 2020). For example, females tend to prefer the Converger learning style, which emphasizes comprehension and practical application, while males often prefer the Assimilator learning style, which focuses on abstract conceptualization and reflective observation (Awofala et al., 2020)

In addition, differences in brain activation have also been found to contribute to students' approach to mathematics. Males are more dominant in abstract reasoning, while females excel in detail processing and working memory (Hill et al., 2014; Ganley & Vasilyeva, 2014). Psychological factors, such as higher math anxiety in females, also affect their self-efficacy (Wang et al., 2020).

Various studies have confirmed this difference. Fennema and Sherman (1977) and Keller (2020) found a gender gap in MPSA. Other studies have shown differences in math performance and approaches between male and female students. However, these differences are often contextual (Liu, 2009; Mashuri & Yawan, 2023).

Regarding mathematical disposition, (Casad et al., 2017) found significant differences between male and female students, which were mainly influenced by gender stereotypes in mathematics. Meanwhile, (Recber et al., 2018) found that gender plays an important role in shaping mathematical dispositions, especially through the dimensions of self-efficacy, anxiety, and attitude toward mathematics.

Although gender differences in the context of dispositions and mathematical problem-solving ability have been widely researched, this study still examines gender aspects as a complementary goal. This is important to (1) enrich the understanding of the role of gender in the specific contribution of mathematical disposition indicators on the MPSA, (2) expand the

geographical scope of similar research, and (3) provide more contextualized insights into the mathematics education setting in Indonesia.

Based on the above literature review and to achieve the stated research objectives, this study was designed to systematically answer a series of interrelated questions. The questions were systematically structured, from exploring students' basic ability levels to analyzing the relationships between variables and gender differences. Research hypotheses were developed based on previous empirical findings to test the relationships between variables and gender differences. Specifically, this article addresses the following research questions: (1) What is the MPSA level of tenth grade high school students? (2) What is the MPSA level of tenth grade high school students? (3) Does MD have a significant influence on students' MPSA? (4) Does each indicator of MD significantly influence students' MPSA? (5) Which MD indicator has the most significant influence on students' MPSA? (6) Is there a significant difference in the MD of male and female students? (7) Is there a significant difference in MPSA of male and female students?

The findings from this study regarding the relationship between MD (including the specific contributions of its seven indicators), MPSA, and gender differences are expected to provide an empirical foundation for developing more effective and gender-responsive mathematics learning strategies.

In developing an instrument to measure mathematical disposition, this study refers to the indicators proposed by the National Council of Teachers of Mathematics (NCTM, 2000, 2014), namely: (1) mathematical self-efficacy; (2) mathematical flexibility of thinking; (3) mathematical persistence; (4) mathematical curiosity and creativity; (5) mathematical

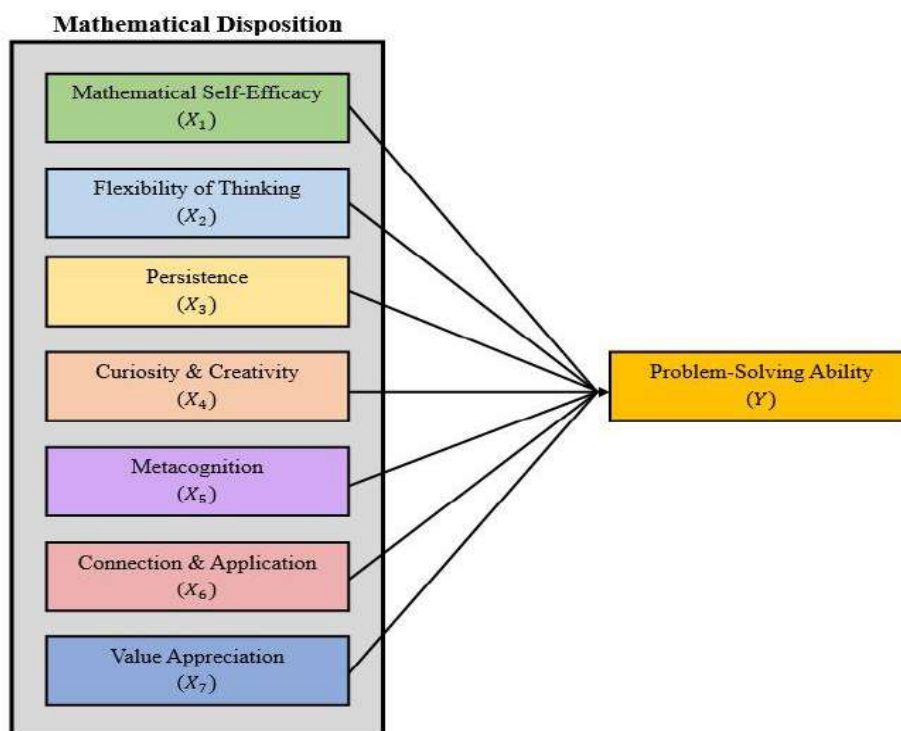


Figure 1. Research Design Study

metacognition; (6) mathematical connections and applications; (7) mathematical value appreciation. Appreciation of the value of mathematics.

METHOD

Research Type and Design

This study utilizes an ex post facto research design, a non-experimental approach widely employed in education and social science research. The ex post facto research design is appropriate for investigating phenomena that have already occurred and cannot be manipulated by the researcher (Coe et al., 2021). This method allows us to examine the relationship between mathematical problem-solving ability, mathematical disposition, and gender. Furthermore, the ex post facto design allows for the examination of several variables simultaneously, which is particularly important for our research as we investigate the complex interactions between mathematical problem-solving ability, various indicators of mathematical

disposition, and gender. This comprehensive approach provides a deeper understanding of the factors influencing mathematics performance and attitudes among secondary school students. The research design is shown in Figure 1.

From Figure 1, (1) The **Independent variable (Mathematical Disposition)** is comprised of seven indicators. This variable is quantified through the administration of a questionnaire, which aims to ascertain its impact on students' capacity to solve problems; (2) **Dependent variable (Problem-solving Ability)**. This variable is quantified through the administration of a mathematics problem-solving assessment; (3) **Moderator Variable (Gender)**. This variable is employed to ascertain whether there are notable discrepancies in mathematical disposition and problem-solving proficiency—furthermore, gender functions as a moderating variable that influences the relationship between mathematical disposition and problem-solving ability.

The research stages included the

following: (1) The requisite ethical and official permits have been obtained; (2) the research sample of 300 students using the Purposive Stratified Cluster Random Sampling technique has been determined; (3) the research instrument, comprising a mathematics disposition questionnaire and a mathematics problem-solving ability test, has been validated by experts and tested. The results demonstrated the validity and reliability of the research. The research hypothesis was established, the data was collected, the statistical methods used to analyze the data, including descriptive statistics, inferential statistics (multiple regression and t-test), and the statistical software employed (SPSS), was determined, the results of the statistical analysis were interpreted, and the results were reported.

Research Subject

This study was conducted in South Sulawesi, Indonesia, comprising twenty-one districts and three cities. The study encompassed six educational institutions, three within the city and three outside. The research sample was established using the purposive stratified cluster random sampling technique. The sampling process was structured as follows: (1) The initial step involved identifying an odd-semester high school class of students in the 10th grade. The rationale for this decision is that the 10th grade is a transitional period between junior high school and high school, and thus, the findings of this study may be indicative of the junior high school level; (2) South Sulawesi's senior high schools (SMA) were stratified based on geographical location (city and outside the city); (3) schools were grouped into clusters based on district/city area. Three districts were randomly selected from the twenty-one districts in the region, and three cities were retained as separate

clusters; (4) from each selected cluster (three districts and three cities), one school was randomly selected, resulting in six schools being selected; (5) from the six selected schools, 50 students each were randomly selected, including 25 boys and 25 girls, resulting in a total of 300 students, consisting of 150 boys and 150 girls. The profile of the research subjects is presented in Table 1.

Table 1. Profile of Quantitative Research Subjects

| Location | School Status | Accreditation | Number of subjects | Number of Subjects by gender | |
|--------------------------|---------------|---------------|--------------------|------------------------------|-----|
| | | | | M | F |
| A1 City | State | A | 50 | 25 | 25 |
| A2 City | Private | A | 50 | 25 | 25 |
| A3 City | Private | B | 50 | 25 | 25 |
| B1 district | State | B | 50 | 25 | 25 |
| B2 district | State | A | 50 | 25 | 25 |
| B3 District | State | C | 50 | 25 | 25 |
| Total number of subjects | | | 300 | 150 | 150 |

Research Instruments

The present study employed two instruments: the MDQ (Mathematical Disposition Questionnaire) and the Mathematics Problem Solving Ability Test. The MDQ was developed by the NCTM indicators (2000, 2014). Each indicator is comprised of six statement items, three of which are favorable and three of which are unfavorable. Thus, the total number of items is 42. The questionnaire is a Likert scale, with gradations from strongly disagree to strongly agree. The response options were "strongly disagree," "disagree," "agree," and "strongly agree." Five experts validated the questionnaire using a validation sheet. The results of the expert assessment demonstrated a Content Validity Ratio (CVR) = 100%, indicating that the questionnaire measures what it is intended to measure. The questionnaire was then tested on 57 students, and the results showed a Cronbach's Alpha = 0.75, indicating good internal consistency. This

means that the items in the questionnaire are highly correlated, suggesting that the MDQ is a valid and reliable instrument.

The instrument for the Mathematics Problem Solving Ability Test was adapted from the PISA problem, consisting of four context problems. One problem concerns number pattern (exhibition context), one problem concerns systems of linear equations (shopping context), one problem concerns elevation angles (eruption mountain context), and one problem concerns reading statistical graphs (business context). The test was validated by five experts with a Content Validity Ratio (CVR) = 100%. Additionally, the test exhibited reliability, as evidenced by a Cronbach's Alpha = 0.72, based on the results obtained from 57 students. This indicates that the problem-solving ability test exhibits satisfactory validity and reliability. Moreover, each instrument is accompanied by a scoring rubric and defined

categories.

Instrument, scoring rubric, and categories are presented in the link below: https://drive.google.com/file/d/1d_sH0JFgob00oIVjB2DLA5DfPn70p_l1/view?usp=sharing

Data Collection and Analysis

The data were collected from a diverse and inclusive sample of 300 high school students in the 10th grade, with an equal number of male and female students (150 males and 150 females). This diversity ensures that the study's findings represent both genders and a broad population. The study employed the mathematics problem-solving ability test and the mathematics disposition questionnaire (MDQ) as research instruments. Quantitative data analysis was conducted using statistical software, employing various analytical techniques. First, descriptive statistics were employed to characterize the extent

Table 2. Descriptive statistics for Mathematical Problem-Solving Ability (MPSA)

| Question number | Score Interval, Frequency, and percentage | | | | | | | | | | Data centering measure | | |
|-----------------|---|-----|---------|------|---------|------|---------|------|--------|------|------------------------|------|------|
| | 85≤X≤100 | | 70≤X<85 | | 55≤X<70 | | 40≤X<55 | | 0≤X<40 | | Mean | SD | Max |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | | | |
| All questions | 0 | 0 | 14 | 4.7 | 73 | 24.3 | 132 | 44.0 | 81 | 27.0 | 47.1 | 12.9 | 78.1 |
| Questions- 1 | 21 | 7.0 | 48 | 16.0 | 89 | 29.7 | 99 | 33.0 | 43 | 14.3 | 57.3 | 15.5 | 87.5 |
| Questions- 2 | 6 | 2.0 | 29 | 9.7 | 85 | 28.3 | 100 | 33.3 | 80 | 26.7 | 51.8 | 15.0 | 87.5 |
| Questions- 3 | 0 | 0.0 | 13 | 4.3 | 69 | 23.0 | 115 | 38.3 | 103 | 34.3 | 46.3 | 13.8 | 75.0 |
| questions -4 | 0 | 0.0 | 0 | 0.0 | 17 | 5.7 | 59 | 19.7 | 224 | 74.7 | 33.1 | 13.3 | 68.8 |

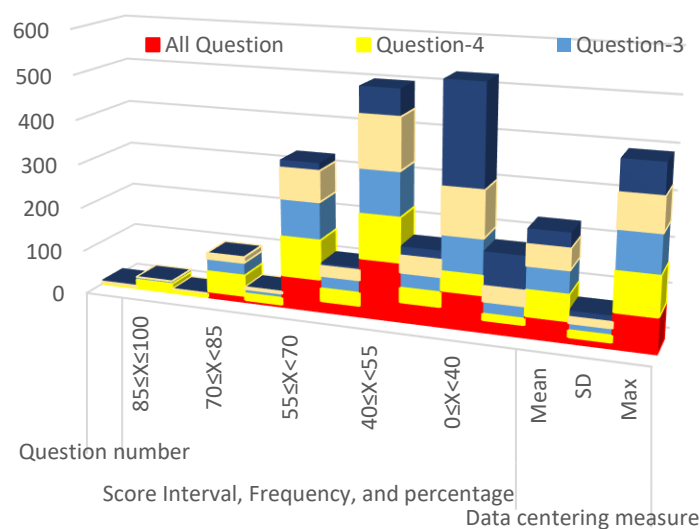


Figure 2. Visualization of mathematical problem-solving (MPSA) test scores

of students' problem-solving abilities and mathematical dispositions. Subsequently, an independent t-test was employed to ascertain the discrepancies between male and female students concerning their mathematical disposition and problem-solving abilities. Moreover, a multiple regression analysis was performed to investigate the influence of mathematical disposition on mathematical problem-solving ability.

RESULT AND DISCUSSION

Result

Descriptive Findings

A descriptive analysis was conducted to gain insight into the data distribution characteristics of each variable under study. This entailed calculating measures of central tendency, including the mean and median, as well as measures of

variability, such as the standard deviation and range. These calculations were performed on data about mathematics problem-solving test scores and mathematics disposition scores, with comparisons by gender also included.

Table 2 presents the descriptive statistics for the mathematical problem-solving ability (MPSA) test scores. Table 3 presents the descriptive statistics for mathematical disposition (MD) scores. Table 4 The following Table 2, 3, 4 present the descriptive statistics for MPSA and MD test scores by gender.

As shown in Table 2 and Figure 2, the mean score of students' MPSA falls into the low category, with a mean score of 47.1 and a standard deviation of 12.9. The distribution of scores reveals that most students (71%) were in the 'Low' or 'Very Low' category, with 44.0% in the 'Low' category and 27.0% in the 'Very Low' category. Only 4.7% of students achieved the 'High' category, and no

Table 3. Descriptive Statistics for Mathematical Disposition (MD) scores

| Indicator | Score Interval, Frequency, and percentage | | | | | | | | | | Data centering measure | | |
|-----------|---|-----|---------|------|---------|------|---------|------|---------|------|------------------------|------|------|
| | 85≤X≤100 | | 70≤X<85 | | 55≤X<70 | | 40≤X<55 | | 25≤X<40 | | Mean | SD | Max |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | | | |
| All | 0 | 0.0 | 0 | 0.0 | 67 | 22.3 | 226 | 75.3 | 7 | 2.3 | 51.1 | 5.3 | 38.1 |
| X1 | 6 | 2.0 | 233 | 77.7 | 43 | 14.3 | 18 | 6.0 | 0 | 0.0 | 72.7 | 8.6 | 87.5 |
| X2 | 0 | 0.0 | 0 | 0.0 | 23 | 7.7 | 129 | 43.0 | 148 | 49.3 | 52.4 | 6.5 | 66.7 |
| X3 | 0 | 0 | 0 | 0 | 93 | 31 | 207 | 69 | 0 | 0 | 43.5 | 8.0 | 66.7 |
| X4 | 0 | 0.0 | 0 | 0.0 | 13 | 4.3 | 168 | 56.0 | 119 | 39.7 | 43.5 | 8.0 | 66.7 |
| X5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 73 | 24.3 | 227 | 75.7 | 36.0 | 4.6 | 50.0 |
| X6 | 0 | 0.0 | 3 | 1.0 | 29 | 9.7 | 246 | 82.0 | 22 | 7.3 | 48.2 | 7.4 | 75.0 |
| X7 | 0 | 0.0 | 121 | 40.3 | 89 | 29.7 | 90 | 30.0 | 0 | 0.0 | 63.8 | 10.7 | 83.3 |

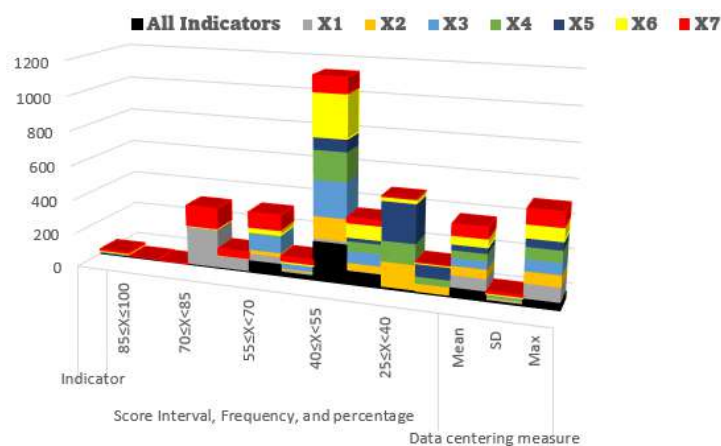


Figure 3. Visualization of mathematics disposition (MD) scores

students reached the 'Very High' category. This assessment is a crucial tool in understanding student performance and identifying areas for improvement.

Upon closer examination, it's clear that students need help across all MPSA items. However, one item stands out-item number 4, which involves reading statistical graphs. Students showed significant difficulties with this item, as indicated by an average score of only 33.1, with 74.7% of students falling into the 'deficient' category.

Table 3 and Figure 3 illustrate that students' mathematical disposition (MD) is within the low category. This is indicated by the mean score of 51.1 with a standard deviation 5.3. Most students (75.3%) were classified within the "Low" category, while 22.3% were placed within the "Medium" category. No students demonstrated a level of mathematical

disposition (MD) that could be classified as "high" or "very high."

Further analysis of MD indicators revealed that students exhibited low MD and demonstrated deficient levels of the following indicators: mathematical metacognition, the flexibility of mathematical thinking, mathematical persistence, mathematical curiosity and creativity, and mathematical connections and applications.

As illustrated in Table 4 and Figure 4, our study has found a marked gender-based gap in problem-solving ability among students. The mean score of females (48.2) was higher than the mean score of males (46.2), indicating a descriptive difference. In addition, the proportion of female students in the highest category (5.3%) was more significant than that of male students in the same category (4%). Similarly, the mathematical disposition of

Table 4. Descriptive Statistics for MPSA and MD test scores by Gender

| Variable | Gender | Score Interval, Frequency, and percentage | | | | | | | | | | Data centering measure | |
|----------|--------|---|-----|---------|-----|---------|------|---------|------|----------|------|------------------------|------|
| | | 85≤X≤100 | | 70≤X<85 | | 55≤X<70 | | 40≤X<55 | | 0≤X<40*) | | Mean | SD |
| | | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | | |
| MPSA | M | 0 | 0.0 | 6 | 4.0 | 34 | 22.7 | 67 | 44.7 | 43 | 28.7 | 46.0 | 12.2 |
| | F | 0 | 0.0 | 8 | 5.3 | 39 | 26.0 | 65 | 43.3 | 38 | 25.3 | 48.2 | 12.9 |
| MD | M | 0 | 0.0 | 0 | 0.0 | 38 | 19.3 | 110 | 77.3 | 2 | 3.3 | 50.4 | 5.3 |
| | F | 0 | 0.0 | 0 | 0.0 | 38 | 25.3 | 110 | 73.3 | 2 | 1.3 | 51.7 | 5.2 |

*) for MD score ($25 \leq X < 40$)

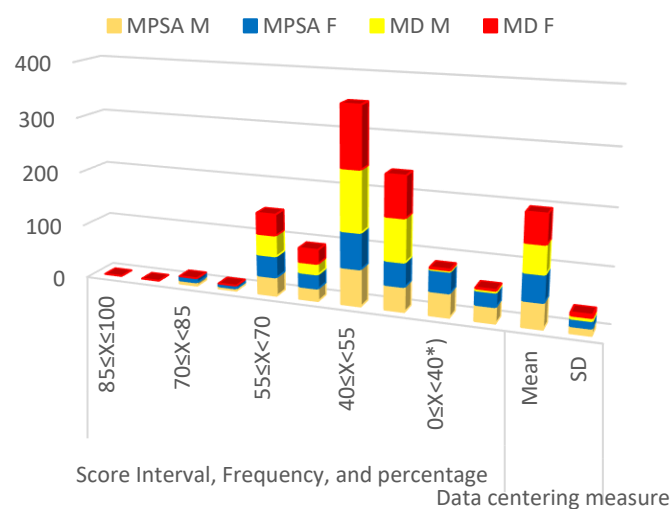


Figure 4. Visualization of MPSA and MD test scores by gender

male and female students also showed descriptive differences. The mean score for female students (51.7) was higher than that of male students (50.4), and the proportion of female students in the moderate category (25.3%) was higher than that of male students in the high category (19.3%). These key findings underscore the impact of our research in understanding and addressing gender disparities in education.

Inferential Findings

Before employing multiple regression, a comprehensive series of prerequisite tests are conducted. These tests cover a range of factors including normality, heteroscedasticity, and multicollinearity, ensuring a thorough and robust analysis (Alita et al., 2021; Williams et al., 2019).

Table 5 displays the outcomes of the multiple linear regression prerequisite tests. These tests are based on the relationship between the dependent variable, mathematical problem-solving ability (Y), and the independent variable, mathematical disposition (X), which is a composite of seven key indicators. These indicators, each with its own significant contribution, are crucial in understanding problem-solving ability and are as follows:

- X1: mathematical self-efficacy; X2: mathematical flexibility of thinking; X3: mathematical persistence; X4: mathematical curiosity and creativity; X5: mathematical metacognition; X6: Mathematical connection and application; X7: Mathematical value appreciation.

Table 5. Multiple Linear Regression prerequisite test results

| Statistical Test | Variable | | | | | | | |
|------------------|----------|-------|-------|-------|-------|-------|-------|-------|
| | Y | X1 | X2 | X3 | X4 | X5 | X6 | X7 |
| S1 | 0.57 | 0.61 | 0.59 | 0.63 | 0.58 | 0.64 | 0.56 | 0.54 |
| S2 | 0.114 | 0.883 | 0.997 | 0.124 | 0.328 | 0.075 | 0.117 | 0.124 |
| S3 | 1.451 | 1.608 | 1.269 | 2.345 | 1.857 | 2.806 | 2.148 | 1.451 |

S1: Normality (Kolmogorov-Smirnov); S2: Heteroscedasticity (sig.); S3: Multicollinearity (tolerance)

Table 5 demonstrates that the data for all variables are normally distributed (sig. value > 0.05). Additionally, the data exhibit no indications of heteroscedasticity (sig. value > 0.05). Furthermore, no multicollinearity symptoms exist in any of the variables (Tolerance value > 0.10). Therefore, the prerequisites for employing multiple linear regression have been satisfied.

The results of the multiple regression calculations, conducted using the statistical software SPSS, are presented in Tables 6 and 7.

Table 6. Summary of Multiple Linear Regression Models and Analysis of Variance (ANOVA)

| Aspects | Results |
|---------------|--|
| Model Summary | R = 0.598, R ² = 0.595, Adjusted R ² = 0.595 |
| ANOVA | F = 8492.173, Sig. = 0.000 |

Table 7. Regression Coefficient of Mathematical Disposition (MD) Indicator

| Variable | Coefficient (B) | Std. Error | Beta | t | Sig. |
|------------|-----------------|------------|-------|----------|-------|
| (Constant) | -75.521 | 0.604 | - | -125.026 | 0.000 |
| X1 | 0.358 | 0.007 | 0.237 | 48.089 | 0.000 |
| X2 | 0.325 | 0.009 | 0.189 | 36.436 | 0.000 |
| X3 | 0.341 | 0.009 | 0.172 | 37.307 | 0.000 |
| X4 | 0.399 | 0.010 | 0.246 | 39.260 | 0.000 |
| X5 | 0.273 | 0.016 | 0.097 | 17.451 | 0.000 |
| X6 | 0.326 | 0.012 | 0.186 | 27.102 | 0.000 |
| X7 | 0.354 | 0.007 | 0.293 | 48.903 | 0.000 |

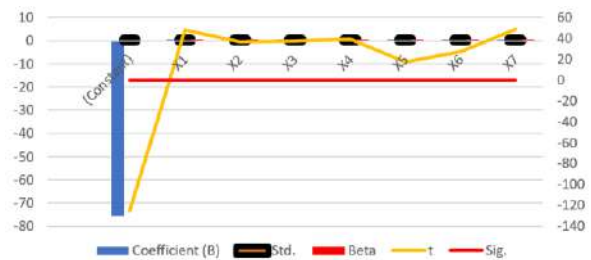


Figure 5. Visualization of regression coefficients

As illustrated in Tables 6 and 7 and Figure 5, the regression model demonstrates a high level of predictive capacity, as evidenced by an R² value of 0.595. This suggests that 59.5% of students' mathematical problem-solving proficiency variability can be attributed to the seven indicators

of mathematical disposition examined. Moreover, the ANOVA test yielded an F-value = 8492.173 with a p-value < 0.05 , indicating that the regression model is statistically significant in predicting students' mathematical problem-solving ability. Moreover, the significance value of 0.000 for all indicators indicates that all indicators of mathematical disposition positively and significantly impact students' mathematical problem-solving ability.

The standardized beta coefficient values indicate that the order of the contribution of the mathematical disposition indicators, from largest to smallest, is as follows: mathematical value appreciation demonstrates the most significant contribution, followed by mathematical curiosity, creativity, and mathematical self-efficacy. Moreover, mathematical flexibility of thinking is associated with a value marginally higher than that of mathematical connections and applications. Mathematical persistence is sixth, while mathematical metacognition shows the most minor contribution but remains significant.

The results demonstrate that each indicator of mathematical disposition plays a substantial role in students' mathematical problem-solving abilities, with notable variations in its influence. Notwithstanding the discrepancies in the beta coefficient values, all indicators exhibited a substantial positive correlation with the dependent variable.

MPSA and MD by Gender

This section is dedicated to a research question of profound significance: Do gender-based differences exist in problem-solving ability and mathematical disposition? This question, with its potential to inform and shape our understanding of cognitive disparities, is the cornerstone of our study.

The independent sample t-test will

be employed to ascertain whether the mean difference between the two groups (male and female) is statistically significant.

Before embarking on the independent sample t-test, we meticulously conducted normality and homogeneity tests, as recommended by Alita *et al.* (2021) and Williams *et al.* (2019). These tests, presented in table 8, were performed using the robust statistical software program SPSS, ensuring the reliability of our results.

Table 8. Prerequisite Test Results of independent sample t-test

| Variables | Normality Test (Kolmogorov-Smirnov) | | Homogeneity test (sig.) | |
|-----------|--|-------|----------------------------|----------|
| | P | W | Based on | Based on |
| | | | Mean | Median |
| MPSA | 0.082 | 0.285 | 0.659 | 0.652 |
| MD | 0.065 | 0.96 | 822 | 0.817 |

As illustrated in Table 8, the data exhibits a normal distribution and is homogeneous, enabling the application of the independent sample t-test to assess the research hypothesis. The results of the independent sample t-test, as calculated in SPSS, are presented in Table 9.

Table 9. Hasil Uji Independent Sample T-Test MPSA dan MD Berdasarkan Gender

| Variables | t | df | Sig. (2-tailed) | Mean Difference |
|-----------|--------|-----|-----------------|-----------------|
| MPSA | -1.504 | 298 | 0.134 | -2.2393 |
| MD | -2.125 | 298 | 0.034 | -1.2980 |

Table 9 indicates no statistically significant difference in problem-solving ability between male and female students. The value of Sig evidence this. (2-tailed) = $0.134 > 0.05$. Conversely, the mathematical disposition between male and female students is significantly different. This is demonstrated by the Sig value (2-tailed) = $0.034 < 0.05$.

Discussion

This study explored the relationship between Mathematical Problem Solving Ability (MPSA), Mathematical Disposition (MD), and Gender among grade 10 students in South Sulawesi, Indonesia. Overall, the findings indicate that students' MPSA and MD levels are in the low category, in line with the research results of Attami et al. (2020), Zhang et al. (2023), and Tampa et al. (2022). Similar phenomena have been identified across different geographical contexts by Zhang et al. (2023), indicating that this challenge is global in mathematics education. In addition, this study confirmed the positive influence of MD on MPSA, which emphasizes the important role of mathematical disposition in mathematics learning. These findings reinforce previous research by Hutajulu and Hidayat (2023), Pajares and Miller (1995), and Busnawir et al. (2023), which highlighted the important role of MD in improving problem-solving ability. The discussion focuses on two interesting findings for deeper analysis:

Gender Paradox in MD and MPSA

The study revealed an interesting phenomenon where no gender differences were found in MPSA, yet there were significant differences in MD. This paradox can be explained through several critical perspectives.

First, the absence of gender differences in MPSA could be attributed to the compensatory mechanisms adopted by students. Research shows that students with lower MD often develop compensatory strategies such as seeking peer support, dedicating additional study time, or consulting teachers to overcome their deficiencies (Fredricks et al., 2018). These strategies allow students to achieve comparable levels of MPSA performance despite differences in MD. Research by

Borgonovi et al. (2023) showed that female students are more likely to seek peer help, while male students prefer individual exploration when facing math problems. These approaches yielded comparable results despite differences in learning styles.

Secondly, contextual factors such as gender equality-based education reforms also contribute to creating a more inclusive learning environment. Contemporary teaching methods, such as problem-based and collaborative learning, allow students from different ability backgrounds to contribute effectively to the learning process (Nurjanah et al., 2019). These approaches accommodate different learning styles, whether based on abstract reasoning or observational learning, thus reducing the negative impact of the MD gap on MPSA outcomes.

Third, reducing gender stereotypes in mathematics education has increased female students' engagement in problem-solving activities. Teachers who are more aware of the importance of gender equity often provide equal encouragement to both male and female students, fostering a classroom atmosphere that supports active participation from all students (Casad et al., 2017). This demonstrates that while gender differences in mathematical disposition exist, social support and equitable learning environments can mitigate their impact on academic outcomes.

Fourth, the adaptability of modern assessment systems has also contributed to the equalization of MPSA outcomes. These systems, which focus on results and the problem-solving process, creativity, and diverse solution approaches (Taylor et al., 2024), can accommodate various problem-solving styles, which may differ between genders. This adaptability offers equal opportunities for all students to demonstrate their abilities, reassuring the audience about the fairness of the

evaluation process.

Fifth, the role of educational technology in modern mathematics education has helped bridge the gap in mathematical disposition between genders. Digital learning platforms and technological tools provide various means to understand and solve mathematical problems, enabling students to choose approaches that best suit their learning styles (Abidin *et al.*, 2018). Research indicates that female students are more comfortable with visual-interactive approaches, whereas male students tend to focus on mathematical abstraction. This helps balance differences in mathematical disposition and ensures equal access to learning resources.

Sixth, this study also suggests that differences in mathematical disposition may reflect self-perception and socio-cultural factors rather than actual problem-solving abilities. Longitudinal studies indicate that gender differences in mathematical disposition are often shaped by societal expectations and cultural stereotypes (Chan, 2022). However, both genders can demonstrate equivalent problem-solving skills when given appropriate opportunities and support.

The Dominance of Appreciation for Mathematics Grades: Analyzing Its Relationship with the MPSA

The significant shift from the traditional emphasis on mathematics self-efficacy to the importance of 'appreciation of mathematics value' as the strongest predictor of the MPSA is an important finding. This contrasts with previous research, such as that conducted by Krawitz & Schukajlow (2018). This underscores the need for a deeper analysis of the role of mathematics value appreciation in mathematics learning, particularly in relation to the MPSA.

Appreciation of the value of mathematics plays an important role in fostering stable intrinsic motivation. Unlike self-efficacy, which is often situational and fluctuates, value appreciation provides stronger and longer-term motivation. When students understand the relevance of math in real life, they not only show greater resilience in the face of mathematical challenges, but also develop a deeper appreciation for the subject. This intrinsic motivation encourages students to delve deeper into abstract concepts and to seek conceptual understanding rather than procedural knowledge (Rodríguez *et al.*, 2021). For example, students who have a high appreciation of the value of mathematics tend to view math as an important tool for solving real-world problems, which ultimately increases their perseverance in learning.

Understanding the long-term relevance of mathematics is not just a matter of perception, but also has a significant influence on students' cognitive processes. Those who appreciate the practical importance of mathematics are better able to connect abstract concepts with real-world applications, such as using geometry in architectural design or statistics in data analysis (Hohol & Miłkowski, 2019). This knowledge transfer process is particularly important in problem solving, where students must integrate theory with concrete situations that demand cognitive flexibility. Research shows that students with a high appreciation of the value of mathematics are more adept at identifying patterns, formulating strategies, and applying appropriate approaches to solving mathematical problems (Matthews, 2018).

Moreover, appreciation of the value of mathematics is not only a theoretical concept, but also a practical tool that helps students to maintain perseverance when facing obstacles. Students who

have a positive view of the relevance of mathematics are more likely to try different strategies to find solutions and reflect on their mistakes rather than giving up when facing difficulties. This perseverance allows them to achieve better results, even in consistently complex problems (Barnes, 2019). In this regard, appreciation of the value of mathematics provides a practical framework that supports students continued cognitive exploration.

Unlike dispositional indicators, such as self-efficacy or cognitive flexibility, value appreciation forms the motivational foundation that drives exploration and sustains learning. While self-efficacy is critical for building students' confidence to try, without an appreciation of mathematical values, this motivation may not be sufficient to encourage deep exploration or complex problem solving (Voica et al., 2020). In contrast, combining a high appreciation of the value of mathematics with moderate self-efficacy results in optimal problem-solving performance, as evidenced by recent research (Du et al., 2021).

This multi-perspective analysis underscores the potential of pedagogical interventions to bridge the gap between mathematical disposition and problem-solving ability based on gender. It offers hope for the future of gender equity in education, showing that with the right interventions and systemic support, the gap can be effectively bridged.

Implications of Research

The findings from this study make significant contributions to various aspects of mathematics education.

For educational practitioners, the results of this study highlight the importance of teachers developing learning strategies that focus on problem solving skills and actively foster positive

mathematical dispositions. One potential strategy is local context-based differentiated instruction, which helps students learn mathematics meaningfully by connecting it to real-life experiences. In addition, teachers should also utilize *assessment for learning* and *assessment as learning* to provide richer feedback. Diverse assessment methods, such as portfolios and performance-based assessments, can be used to support more holistic learning.

At the policy level, this research underscores the need for professional development programs, including training to design differentiated learning tools and adaptive technologies. Such technologies include digital learning platforms that enable personalization of materials and evaluation. This support will assist teachers in designing innovative and student-centered teaching, while improving the overall quality of learning.

Limitations

This study has some limitations that must be acknowledged. Methodologically, the ex-post facto design limits the ability to draw causal inferences between MD and MPSA variables. Potential biases in the research instruments, particularly in measuring MD, should also be considered. The external validity of the findings is limited by the sample being confined to one region, and the influence of socio-cultural factors on the reliability of MD measurement has not been fully controlled.

The context of the study also has limitations, such as not including variables such as socioeconomic status, teaching quality, and learning environment. The influence of culture on MD and the role of parental and community support have not been explored in depth. In addition, this study did not analyze the interaction between gender, social status and culture in MPSA.

Future research directions include a more in-depth exploration of the interactions between gender, MD and MPSA and the development of models that integrate contextual factors. Longitudinal studies are needed to understand the development of MD and the mechanism of the MD-MPSA relationship. Experimental approaches can be used to test the effectiveness of specific interventions, while cross-cultural and geographical studies can extend the generalizability of findings.

Practical applications include testing the effectiveness of instructional strategies differentiated instructional strategies based on local contexts in improving MD and MPSA. Technology-based intervention programs, such as adaptive digital platforms, should be validated to ensure personalized learning supports MD development. Research on the application of gender-responsive learning strategies in various local contexts is an important step to ensure alignment with students' needs.

CONCLUSIONS

This study found a significant relationship between mathematical disposition and mathematical problem-solving ability based on gender among grade 10 students in South Sulawesi, Indonesia. The main findings showed that most students showed low levels of problem-solving ability and mathematical disposition. All indicators of mathematical disposition were found to significantly influence problem-solving ability, with appreciation of the value of mathematics identified as the largest contributor. While there was no significant difference in problem-solving ability between male and female students, a significant difference was seen in their mathematical disposition. These findings underscore the importance of developing learning strategies that prioritize improving problem-solving ability and fostering positive mathematical dispositions, considering gender differences. The

findings of this study not only provide a solid foundation for developing a more comprehensive and responsive approach to mathematics education and open new avenues for future research in this area.

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Students' Geometric Creative Thinking Skills: An Analytical Study

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Abstract

This research is important to find out how students' creative thinking skills are in understanding the basic teaching materials of geometry. We can use this knowledge to design or develop more innovative and effective learning methods. If a student learns more about his ability to understand and apply the basic concepts of geometry, it will enable him to develop his ability further. The study aims to identify and analyze the level of students' creative geometric thinking skills on the geometrical material. The research uses qualitative descriptive methods, with data collection through tests, evaluation sections, and interviews. The research sample was taken from students in a mathematics study program at a private university in Riau Province. The tests are given to measure students' mathematical creative thinking skills in the geometry material, while the assessment and interview sections are used to gain a deeper understanding of how students use their creativity in understanding and applying the concepts of geometry so that the level of creativity can be identified. We also use interviews to validate the results of student tests. The results show that students' creative thinking skills are at the stage of identifying, describing, and understanding the basics of geometry, such as point, matter, lines, and angles. Students have varying levels of understanding of visualization, analysis, and informal. Nevertheless, students have demonstrated creative thinking skills in analyzing the images given, especially on the subject where students refer to indicators of fluency, flexibility, originality, and elaboration. Although not entirely original, they are able to combine existing concepts in an informative and detailed manner. The explanations provided in the question's answer offer significant and pertinent details about the concepts of points, lines, and angles, highlighting their interrelatedness. Students can also elucidate the fundamental definitions of each concept, applying them to both visual aids and supporting evidence. Implications of this research are the development of learning methods and strategies, increased student understanding and creativity in applying concepts of geometry and providing insight into how best to evaluate and evaluate creative thinking skills in a geometric context.

Keywords: Geometry; Mathematical Creative Thinking Ability; Students; Mathematics Education.

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Abstrak

Penelitian ini penting untuk mengetahui bagaimana keterampilan berpikir kreatif mahasiswa dalam memahami materi dasar geometri. Pengetahuan ini dapat dimanfaatkan untuk merancang atau mengembangkan metode pembelajaran yang lebih inovatif dan efektif. Jika mahasiswa mengetahui lebih banyak tentang kemampuannya dalam memahami dan menerapkan konsep materi dasar geometri, maka memungkinkan mahasiswa untuk dapat mengembangkan kemampuannya lebih jauh lagi. Penelitian ini bertujuan untuk mengidentifikasi dan menganalisis tingkat keterampilan berpikir kreatif geometris mahasiswa pada materi geometri. Penelitian ini menggunakan metode deskriptif kualitatif, dengan pengumpulan data melalui tes, rubrik penilaian dan wawancara. Sampel penelitian diambil dari mahasiswa program studi matematika di sebuah universitas swasta di Provinsi Riau. Tes diberikan untuk mengukur kemampuan berpikir kreatif matematis mahasiswa dalam materi geometri, sementara rubrik penilaian dan wawancara digunakan untuk mendapatkan pemahaman yang lebih mendalam tentang bagaimana mahasiswa menggunakan kreativitas mereka dalam memahami dan menerapkan konsep geometri, sehingga tingkat kreatifitas dapat diidentifikasi. Wawancara juga digunakan untuk menguatkan hasil tes mahasiswa. Hasil penelitian menunjukkan bahwa keterampilan berpikir kreatif mahasiswa berada pada tahap mengidentifikasi, menggambarkan, dan memahami dasar-dasar geometri seperti: materi titik, garis, dan sudut. Mahasiswa mampu mencapai tingkat pemahaman visualisasi, analisis, dan informal. Meskipun demikian, mahasiswa telah menunjukkan kemampuan berpikir kreatif dalam menganalisis gambar-gambar yang diberikan, terutama pada soal yang mendosong mahasiswa menunjukkan indikator fluency, flexibility, originality, dan elaboration. Walaupun tidak sepenuhnya orisinal, mereka mampu menggabungkan konsep-konsep yang ada dengan cara yang informatif dan rinci. Penjelasan yang dituliskan dalam menjawab soal memberikan informasi yang berarti dan relevan tentang konsep titik, garis, dan sudut, sehingga dapat dimaknai ketiga konsep ini saling terkait satu sama lain. Mahasiswa juga dapat menjelaskan ketiga konsep tersebut secara detail sehingga definisi dasar masing-masing konsep dapat dijelaskan dan dapat diaplikasikan baik dalam gambar maupun pembuktian. Implikasi dari hasil penelitian ini adalah pengembangan metode dan strategi pembelajaran, peningkatan pemahaman dan kreatifitas mahasiswa dalam menerapkan konsep-konsep geometri, dan memberikan wawasan tentang cara terbaik untuk menilai dan mengevaluasi keterampilan berpikir kreatif dalam konteks geometri.

INTRODUCTION

The ability of mathematical creative thinking is one of the essential aspects in mathematics education. This ability of students is related to generating new ideas, creative solutions, seeing things from new perspectives, and using unconventional approaches to solve mathematical problems so that they can address global issues (Newman, 1989; Siswono, 2016). Additionally, creative thinking is the ability to think beyond conventional patterns; creative thinkers can free themselves from dominant patterns stored in their brains. Therefore, enhancing creative thinking means increasing scores in understanding, fluency, flexibility, and novelty in problem-solving and using new approaches, perspectives, methods, and insights in understanding something (Fakhriyani, 2016; Langrehr, 2020; Umar & Abdullah, 2020). Students' creative thinking abilities can be measured using

four aspects of creative thinking: fluency, flexibility, originality, and elaboration (Mutia et al., 2022).

The ability to think systematically, scientifically, logically, and critically can enhance creativity and help students express opinions or answers to problems with various solutions. Furthermore, the importance of creative thinking that generates new ideas is to solve the problems faced in an ever-changing world (Istianah, 2013; Maulanaizza & Kusumandari, 2023). Moreover, it drives human progress in exploration, development, and new discoveries in the fields of science and technology, as well as in all human endeavors (Ghufron & Suminta, 2010). Additionally, it produces new and varied solutions to problems (Yunianta, 2014). The obstacles in developing mathematical creative thinking skills include habits (Snášel et al., 2017). These habits include: 1) the tradition passed down by teachers that once you can do something, there's no need to

seek alternatives; 2) students prefer to solve problems according to examples; 3) more focus on formulas than considering other alternatives.

Thinking is a mental activity that involves formulating understanding, synthesizing, and drawing conclusions to solve problems, resulting in higher or highest levels of cognitive behavior (Gagné, 1980; Yuwono, 2016). In line with this, (Houwer & Hughes, 2020) suggests that high-level thinking includes both creative and critical thinking. Thinking involves the careful and precise development of ideas, often beginning with a problem (Suryosubroto, 2009). Furthermore, (Lin, 2023) explains that the thinking process is an experience of encountering a problem to generate and determine new ideas as solutions to the problem at hand. Meanwhile, creative thinking is characterized by four components: fluency (generating many ideas), flexibility (shifting perspectives easily), originality (creating something new), and elaboration (developing additional ideas from one idea) (Ahmadi, 2013; Siswono, 2016). Additionally, (Wijngaarden *et al.*, 2021) identified characteristics of creative individuals such as: 1) openness to new experiences, flexible in thinking and responding; 2) tolerance for differing opinions, uncertain situations; 3) freedom in expressing opinions and feelings, enjoys asking questions; 4) appreciation for fantasy, rich in initiative, has original ideas; 5) having their own opinions and not easily influenced by others; 6) having a positive self-image and emotional stability, confident and independent; 7) having a great curiosity, interested in abstract, complex, holistic and puzzling matters, has broad interests; 8) willing to take calculated risks, responsible and committed to tasks; 9) persevering and not easily bored, resourceful in problem-solving; 10) sensitive to environmental situations; 11) more focused on the present

and future than the past. Meanwhile, creative thinking according to other experts is the thinking activity to produce something creative, original, and divergent (Baer, 1991; Kadir *et al.*, 2022; Pehkonen, 1997; Runco & Jaeger, 2012; Sekar *et al.*, 2015; Sunaryo, 2014). So, it can be concluded that the indicators of creative thinking consist of: (fluency), flexibility, originality, and elaboration (Kahfi, 2016; Sitepu, 2019). Based on these descriptions, it can be concluded that thinking is a mental or brain activity that involves formulating, problem-solving, decision-making, efforts to understand something, seeking answers to problems, and seeking meaning in things, which lead to directed discoveries towards a goal. Meanwhile, creative thinking is a process to develop and solve problems to create new ideas or concepts.

The geometry material was chosen because geometry is a branch of mathematics that requires understanding and visualization of space, patterns, properties, and relationships between geometric objects, making it a suitable research topic. Having strong mathematical creativity in geometry will enable students to solve complex geometric problems, gain a deeper understanding of geometric concepts, and improve their mathematical modeling skills (Jones & Tzekaki, 2016; Pujawan *et al.*, 2020; Yahaya, 2005). This research is also important because creative mathematical thinking skills have a strong correlation with the development of problem-solving skills, logic, abstract thinking, and creativity in general. Therefore, understanding students' creative mathematical thinking skills in geometry content can provide insights into the effectiveness of teaching methods and strategies used in this context. By analyzing students' mathematical creative thinking skills in geometry content, this research is expected to provide valuable

information for mathematics educators, curriculum developers, and education practitioners to develop more effective teaching strategies and empower students to develop their mathematical creative thinking skills.

In geometry, the properties of lines, angles, planes, and space are studied. Geometry is a fundamental subject that requires imagination and is an essential part of the curriculum. The concepts of geometry are often encountered in everyday life and play a crucial role in understanding characteristics and relationships, as well as developing critical thinking skills (Istikomah et al., 2022). Concepts are formed through students' direct participation in geometry instruction. Geometry also requires high-level reasoning and problem-solving skills. Students must understand geometric concepts and be able to implement them when recognizing various shapes and spaces, describing, and distinguishing geometric shapes (Istikomah, 2019).

The creative thinking skills of students in geometry need to be analyzed because it can help in understanding the extent to which students are able to develop their creativity in solving geometric problems. The geometric problems referred to include evaluating the understanding of concepts, developing problem-solving skills, identifying student needs, curriculum development, and others. Thus, the urgency of analyzing students' geometric creative thinking skills is not only related to evaluating learning achievements but also to developing students' creative skills and improving the overall effectiveness of mathematics education. Therefore, this study aims to identify and analyze the level of students' mathematical creative thinking skills in the subject of geometry.

METHOD

This research is a qualitative descriptive study. The qualitative approach is an approach to building statement of knowledge based on a constructive perspective (Creswell & Poth, 2016). The method used to achieve the research objectives involves the following stages (See Figure 1).

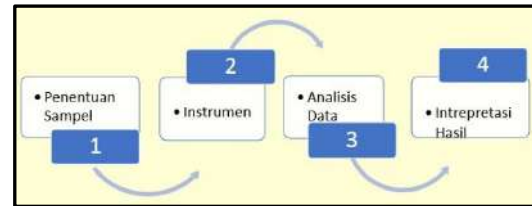


Figure 1. The stages of the research

Sampling Determination

The sample was students from the first semester mathematics education study program. They took geometry courses. The sample selection method is purposive sampling. Purposive sampling is a sampling technique in which the selection of informants is carried out with a specific aim in order to fulfill the main criteria in a study (Creswell, 2014). Purposive sampling was selected by involving students from various backgrounds, talent levels, and levels of experience learning geometry. This aims to be appropriate to the research topic.

Instruments

Mathematical creative thinking assessment and assessment rubric are used as instruments. Test questions are designed based on key concepts of mathematical creative thinking abilities and the geometry curriculum. Interviews are used to gain deeper insights into their mathematical creative thinking abilities. The test instrument is given during the final semester exam. Answer sheets are collected, then

student answers are checked and analyzed one by one. This is to find out whether the questions given can be answered according to the indicators of creative thinking skills, namely: fluency, flexibility, originality and elaboration. Then, student answers are selected that represent these criteria to be discussed.

Data Analysis

After data collection, the analysis assesses students' mathematical creative thinking abilities in geometry. Descriptive statistical techniques such as calculating averages, percentages, or frequency distributions can characterize overall levels of creative mathematical reasoning.

Qualitative analysis can provide a deeper understanding of the mathematical creative thinking strategies used by students.

Interpretation and Presentation of Results

The final stage involves interpreting the results of the data analysis and presenting the research findings. Results can be presented in tables, diagrams, and narratives to provide a clear picture of students' creative mathematical thinking abilities in geometry. The research findings will also be compared with previous studies for a more comprehensive understanding.

This research will begin this year and continue for the next two years. In summary, the research flow is depicted in the flowchart below (See Figure 2).

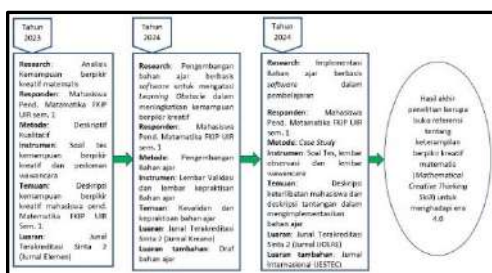


Figure 2. Research Flow Diagram

RESULT AND DISCUSSION

Result

The research results indicate that students' creative thinking skills in point, line, and angle topics show that they can identify, describe, and understand the basics of the subject. This can be seen from question number 1, which is: "a) Explain the Figure 3, b) What should you do first with the images to make it easier for you to analyze or provide comments on the images?, c) Provide lots of correct analysis or comments about the things that apply to each picture accompanied by correct reasons in the form of definitions, postulates/axioms, properties of numbers, etc".

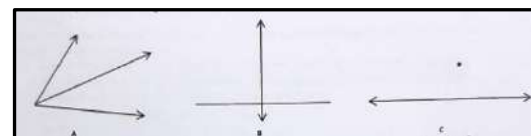


Figure 3. Image for question number 1

Student answers are as shown in Figure 4.

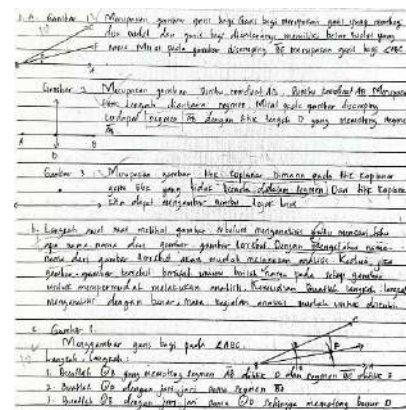


Figure 4. Student answers to number 1

Based on Van Hiele's theory, the analysis of these responses can be seen in terms of the levels of geometric understanding achieved by the participants, in this case, the students. At level 0 (Visualization), the students can identify the images presented in the question by drawing lines in the images and understanding the concept of dividing lines as angle dividers.

At level 1 (Analysis), the students can analyze, draw, and name angles, lines, and segments. Additionally, there is an understanding of the coordinate axis AB as the midpoint between segments. They also mention that coplanar points are points that are not within a segment. This demonstrates an understanding of the relationships between points in a coordinate system. At stage 2 (Informal), the students are not yet able to draw conclusions, do not explain the properties of the angles formed, and do not explain the relationships between points and angles. In stages 3 and 4, namely deduction and rigor, they are not yet evident because the students do not provide proof of their findings and have not written their answers in a sequential and precise manner. Question number 2 provides a theorem: "A triangle is isosceles if two of its angles are congruent. What should you do with the theorem?". The student's answer is as follows in Figure 5.

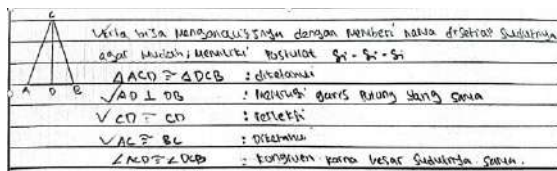


Figure 5. Student answers to question number 2.

Based on Van Hiele's theory, the analysis of the answer can be seen in terms of the level of geometric understanding achieved by the participant, in this case, the student. At level 0 (Visualization), the student can recognize the given theorem and demonstrate an understanding of the concept of an isosceles triangle and congruent angles. At level 1 (Analysis), the student can analyze the triangle and its angles by naming each angle and using the side-side-side postulate to identify triangle congruence. At level 2 (Informal), the student uses informal deductive reasoning by linking the given information (congruent angles) with the

concepts they know (triangle congruence). However, at levels 3 (Deduction) and 4 (Abstraction), there is no evidence that the analysis reaches the level of formal deduction, where individuals can formulate formal proofs to support geometric statements. Additionally, there is no indication that the analysis reaches the level of abstraction, where individuals can understand more complex mathematical concepts in the context of geometry.

Question number 3, Formulation: "If a quadrilateral has a pair of parallel sides, then it has a pair of congruent sides. What should you do with the formulation?". The student's answer is as shown in Figure 6.

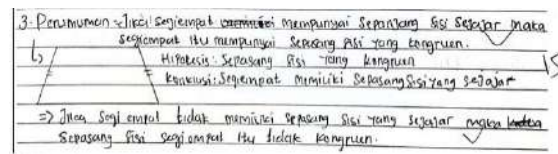


Figure 6. Student answers to question number 3

Based on Van Hiele's theory, the analysis of the answer can be seen in terms of the levels of geometric understanding, namely: At level 0 (Visualization), the student is able to recognize the statement about a quadrilateral having a pair of parallel sides and understand the consequences of that statement. At level 1 (Analysis), the student can analyze the statement by separating the hypothesis (a pair of congruent sides) and the conclusion (the quadrilateral has a pair of parallel sides). The student is also able to use logical reasoning to connect the hypothesis with the conclusion. At level 2 (Informal), the student uses informal deductive reasoning by linking the given information (quadrilateral with a pair of parallel sides) with the concepts they know (congruence of sides). At level 3 (Deduction), the student has not yet shown the ability to construct formal proofs to support geometric statements. Similarly, at level 4 (Abstrac-

tion), the student has not yet demonstrated an understanding of more complex mathematical concepts in the context of geometry. Therefore, the analysis of question number 3 can be said to have reached the levels of visualization, analysis, and informal understanding in Van Hiele's theory, but has not yet reached the levels of formal deduction and abstraction.

Question number 4: Explain the figure 7 below, then provide reasons for your explanation!

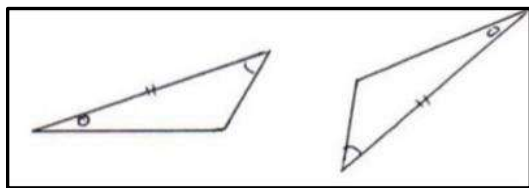


Figure 7. Image for question number 4

Students answered as shown in Figure 8 below:

Based on Van Hiele's theory, the analysis of the answer can be seen in terms of the levels of geometric understanding achieved by the participant, in this case, the student. At level 0 (Visualization), the student can recognize two acute triangles and understand the concept of angles in triangles. At level 1 (Analysis), they can analyze the two triangles by naming their angles (ABC and PQR) and using the side-angle-side postulate to prove triangle congruence. At level 2 (Informal), the student uses informal deductive reasoning by linking the given information (congruence of sides and angles) with the concepts they know (triangle congruence). However, at levels 3 (Deduction) and 4 (Abstraction), the student has not yet been able to present formal proofs to support geometric statements or understand more complex mathematical concepts in the context of geometry. Based on this analysis, it can be concluded that the student has achieved a level of understanding in visualization, informal,

and analysis, but has not yet reached the levels of formal deduction and abstraction.

The creative thinking skills of the students, based on Van Hiele's theory, are at the levels of visualization, analysis, and informal understanding, but have not yet reached the levels of formal deduction and abstraction. If we look at this analysis based on indicators of creative thinking, the student's answer to question number one shows creative thinking skills in analyzing the given images, especially in terms of fluency, flexibility, originality, and elaboration. Although not entirely original in their ideas, they are able to combine existing concepts in an informative and detailed manner.

Discussion

Based on the research findings, the results of this study are important in enhancing the quality of geometry education in schools. By understanding students' level of understanding in geometry, teachers can adapt appropriate teaching methods to enhance students' understanding and creative thinking skills. By understanding the level of students' understanding in geometry, teachers can tailor appropriate teaching methods to enhance students' understanding and creative thinking skills. This means that teachers can adjust their teaching strategies to match the students' current grasp of geometric concepts, ensuring that they receive instruction that is both effective and suitable for their learning needs. Furthermore, the results of this research can serve as a reference for curriculum development and further research in the field of geometry. Therefore, this research can make a significant contribution to improving the quality of education in Indonesia.

The research findings mentioned indicate that students can identify, describe, and understand the basics of geometry, which is the first step in building creative thinking skills. Drawing from the theory of creative thinking skills, this discussion will elucidate how the stages and aspects of these skills contribute to these findings, namely:

Basic Identification and Understanding Stage.

The initial stage of developing creative thinking skills involves basic identification and understanding processes. In the context of research, students have demonstrated this ability through their understanding of points, lines, and angles. According to (Taylor, 2017), fluency, or the ability to generate many ideas, is part of the creative process. In this case, students understand and identify basic geometric concepts, which are the foundation for building further ideas.

Visualization and Analysis.

The ability to visualize and analyze information is the next step in creative thinking. Students demonstrate this ability through their analysis of the provided images. Students' ability to analyze images from various perspectives demonstrates (Rudowicz et al., 1995) emphasis on the importance of flexibility in creative thinking.

Fluency, Flexibility, Originality, and Elaboration.

Research findings show that students show indicators of creative thinking skills through fluency, flexibility, originality, and elaboration. Although not completely original, their ability to combine existing concepts in an informative and detailed

way indicates elaboration or the development of ideas. (Sawyer, 2003) states that creativity involves using existing knowledge to produce something new and useful.

Application and Proof.

In the end, students were able to explain and apply the concepts of points, lines, and angles in detail, which demonstrated their ability to explain and prove these concepts. According to (Kaufman & Sternberg, 2010), these skills reflect an important aspect of creative thinking, namely the application of knowledge in new and different ways.

Creative thinking skills in the context of geometry, as shown in research findings, include a complex process from basic identification and understanding to application and proof. Students demonstrate key aspects of creative thinking such as fluency, flexibility, originality, and elaboration in the analysis and application of geometric concepts. This shows that building a strong foundation in conceptual understanding and encouraging creative exploration of these concepts can improve creative thinking skills in the fields of mathematics and geometry.

The novelty of this research lies in the approach used to analyze students' creative thinking skills in the context of geometry. By utilizing the Van Hiele theory, this study provides a deeper understanding of students' levels of visualization, analysis, informal understanding, formal deduction, and abstraction in comprehending geometry. By employing the Van Hiele theory, this research offers a deeper understanding of students' levels of comprehension in visualization, analysis, informal reasoning, formal deduction, and abstraction concerning geometry. This means that the study delves into how students grasp and process geometric

concepts at various cognitive levels, shedding light on their ability to visualize shapes, analyze their properties, reason informally, deduce formally, and grasp abstract geometric concepts. The Van Hiele theory provides a framework for understanding how students progress through these levels of geometric thinking, which can be valuable for educators in designing effective teaching strategies and materials tailored to students' cognitive development in geometry. Additionally, this research offers a comprehensive analysis of students' responses based on the levels of geometric understanding achieved, along with recommendations for the development of students' creative thinking skills in the context of geometry. Therefore, the novelty of this research lies in the comprehensive analytical approach based on the Van Hiele theory, which can serve as a foundation for the development of teaching methods and curricula in the future context of geometry.

The findings of this research differ from previous studies. Students with specific learning styles determine the level of creativity in solving geometry problems (Restanto & Mampouw, 2018). Prospective teacher candidates can solve Higher Order Thinking Skills (HOTS)-oriented problems at the analysis and evaluation levels. Among the three research subjects, all of them were able to meet the indicators of the analysis and evaluation levels quite well. In terms of creativity, only one prospective teacher was able to meet 2 out of 4 creative indicators. Meanwhile, the other 2 prospective teachers were only able to meet 1 out of 4 creative indicators (Maimunah *et al.*, 2020). The weaknesses of students in process skills lie in errors in using concepts, errors in using data, and errors in using calculation algorithm (Saragih, 2020).

As for the contributions and bene-

fits of this research, they include: 1) Improvement in learning: Teachers can use the results of this research to adjust teaching methods to enhance students' understanding of geometry; 2) Reference for curriculum development: The findings can serve as a reference for developing the mathematics curriculum, particularly in teaching geometry; 3) Reference for future research: Researchers can use this research as a basis for further studies on students' creative thinking skills in geometry; 4) Contribution to education quality: With a better understanding of students' geometry comprehension levels, this research can contribute to efforts to improve the quality of education in Indonesia. Therefore, this research has the potential to have a positive impact on geometry learning and curriculum development in the education context.

Some limitations of this research include: 1) The limited sample size of only 20 students. Future researchers could expand the sample size to obtain more representative results; 2) The focus of this study was on the topics of points, lines, and angles. Subsequent researchers could broaden the scope to examine students' creative thinking skills in other geometry topics. Considering these limitations, future researchers could continue this study with a broader and more in-depth approach to enrich the understanding of students' creative thinking skills in geometry.

Implication of Research

The research highlights the significance of understanding students' levels of geometric comprehension and creative thinking skills, particularly in the topics of points, lines, and angles. Based on Van Hiele's theory, students predominantly operate at the levels of visualization, analysis, and informal reasoning but have not fully reached the advanced stages of formal

deduction and abstraction. This finding underscores the necessity for targeted teaching strategies that align with students' cognitive development stages, fostering deeper understanding and creative exploration of geometric concepts. The study identifies students' creative thinking skills through indicators such as fluency, flexibility, originality, and elaboration, which are foundational to solving geometric problems effectively. Moreover, the research contributes to educational practices by offering insights for curriculum development, instructional adjustments, and further studies on enhancing creative thinking in geometry. While the study demonstrates progress in students' understanding, it also reveals areas for improvement, such as developing formal proof skills and abstract reasoning. These findings provide valuable implications for improving geometry education quality, emphasizing the integration of conceptual clarity with creative and critical thinking development.

Limitation

The limitations of this study include the following: (1) Limited Sample Size: The research involved only 20 students, which may not provide a fully representative understanding of the broader population's creative thinking abilities in geometry. Future studies should include a larger and more diverse sample size to enhance generalizability; (2) Restricted Scope of Topics: The study focused specifically on points, lines, and angles, leaving out other important geometric concepts such as polygons, circles, and three-dimensional shapes. Expanding the range of topics could provide a more comprehensive analysis of students' creative thinking skills in geometry; (3) Reliance on Van Hiele's Theory: While the Van Hiele theory

is a robust framework for assessing geometric understanding, it may not fully capture all aspects of students' creative thinking processes. Future research could incorporate additional theories or frameworks to provide a more holistic view; (4) Limited Time Frame: The study was conducted within a constrained period, which may have restricted the ability to observe longitudinal development in students' geometric understanding and creative thinking skills. Long-term studies are recommended for deeper insights; (5) Dependence on Written Responses: The research relied heavily on analyzing students' written answers, which might not capture the full spectrum of their thought processes. Including verbal explanations or observational methods could enrich the findings.

These limitations highlight areas for improvement and offer directions for future research to deepen understanding of students' creative thinking skills in the context of geometry.

CONCLUSIONS

Based on the research findings, it can be concluded that students' creative thinking skills in the topic of points, lines, and angles demonstrate their ability to identify, describe, and understand the fundamentals of the subject matter. The students can achieve a level of understanding in visualization, analysis, and informal understanding in Van Hiele's theory, but have not yet reached the levels of formal deduction and abstraction. Nevertheless, students have shown creative thinking skills in analyzing the given images, especially in terms of fluency, flexibility, originality, and elaboration. Although their ideas are not entirely original, they are able to combine existing concepts in an informative and detailed manner.

The results of this research are significantly important in improving the quality of geometry education in schools. By knowing the students' level of geometric understanding, teachers can adjust the teaching methods to enhance students' understanding and creative thinking skills. Additionally, the research results can serve as a reference for curriculum development and further research in the field of geometry. Therefore, this research can make a significant contribution to improving the quality of education in Indonesia.

The limitations of this research may include several aspects, such as: 1) the limited sample size of this study. Future researchers can expand the sample size to obtain more representative results; 2) the scope of the material only focuses on the topics of points, lines, and angles. Future researchers can broaden the scope of the material to examine students' creative thinking skills in other geometry topics; 3) the research method only uses descriptive qualitative methods. Future researchers can consider using other methods or a combination of methods to obtain a more comprehensive understanding.

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Developing Google Sites and Mathigon Learning Media to Support Students' Conceptual Understanding in Solving Linear Equations in One Variable

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Abstract

This research notes that there is still a lack of focus on implementing digital-based learning media to help students in understanding of the concept of Linear Equations with One Variable and in finding the solution in one of the East Nusa Tenggara (NTT) State Middle Schools. Virtual balance models can be used to help students learn the concept of linear equations. Therefore, this study aims to develop digital-based learning media, considering the quality criteria of being valid, practical, and effective. The research adopts the Research and Development (R&D) methodology with the ADDIE model (Analyze, Design, Development, Implementation, Evaluation). The research subjects are six seventh-grade students from one of the State Junior High Schools in East Nusa Tenggara with high, moderate, and low cognitive abilities. Data on the quality of learning media are obtained through questionnaires, interviews, and learning outcome tests. The learning media is categorized as highly valid with a percentage of 88% and highly practical with a percentage of 94%. Additionally, the learning media is deemed effective, with over 80% of the research subjects scoring above the Minimum Completion Criteria (KKM). Digital-based learning media utilizing the balance model feature in Mathigon with the help of Google Sites, was developed to facilitate students' understanding of concepts at one of the State Middle Schools in NTT. The problems presented in the media carry the culture that exists in the NTT region. Thus, students can easily imagine these problems because they are close to their lives. Both teachers and students feel assisted by the developed learning media. Using this media, teachers enable to monitor the students' progress and students also can participate actively during this learning.

Keywords: balancing model; conceptual understanding; development; linear equation in one variable

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Abstrak

Penelitian ini mencatat bahwa masih kurangnya fokus pada implementasi media pembelajaran berbasis digital untuk membantu siswa dalam memahami konsep Persamaan Linear Satu Variabel (PLSV) dan penyelesaiannya di salah satu SMP Negeri Nusa Tenggara Timur (NTT). Model keseimbangan virtual dapat dimanfaatkan untuk membantu siswa dalam mempelajari konsep persamaan linear. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan media pembelajaran berbasis digital pada materi persamaan linear satu variabel dengan memperhatikan kualitas yaitu valid, praktis dan efektif. Penelitian ini menggunakan jenis penelitian dan pengembangan atau Research and Development (R&D) dengan model ADDIE (Analyze, Design, Development, Implementation, Evaluation). Subjek penelitian adalah enam peserta didik kelas VII di salah satu SMP Negeri Nusa Tenggara Timur dengan kemampuan kognitif tinggi, sedang dan rendah. Data kualitas media pembelajaran diperoleh dari kuesioner, wawancara dan tes hasil belajar. Media pembelajaran dikategorikan sangat valid dengan persentase 88% dan sangat praktis dengan persentase 94%. Serta media pembelajaran juga dikatakan efektif, lebih dari 80% subjek penelitian mendapatkan nilai diatas Kriteria Ketuntasan Minimal (KKM). Media pembelajaran berbasis digital dengan memanfaatkan fitur model keseimbangan pada Mathigon berbantu Google Sites, dikembangkan untuk memfasilitasi pemahaman konsep siswa di salah satu SMP Negeri di NTT. Permasalahan yang disajikan dalam media tersebut, mengusung budaya yang ada pada daerah NTT. Sehingga siswa dapat dengan mudah membayangkan permasalahan tersebut karena dekat dengan kehidupan mereka. Guru dan peserta didik merasa terbantu dengan media pembelajaran yang telah dikembangkan. Guru dapat memonitoring perkembangan siswa dan siswa melalui media ini dapat terlibat aktif dalam pembelajaran.

INTRODUCTION

In science education, conceptual understanding is to be the primary goal (Konicek-Moran & Keeley, 2015). Especially in mathematics, Syam (2019) said that conceptual understanding is one of ability that must be mastered by students in learning mathematics. With a good grasp of the fundamental concepts, students can solve problems effectively (Fajar et al., 2018). Why? Because conceptual understanding is the comprehension of why you do it, not only what to do it (Cummings, 2015). Therefore, by understanding the concept, students are expected to connect and apply it in their daily life (Syam, 2019).

One of concept in mathematics that is important to solve the daily problems is algebra (Nafii, 2017). Algebra is one of branch in mathematics that be the major component of the mathematics curriculum in most of countries (Bal, 2016). The unknowns, arithmetical operations, variables, expressions, and equations are some concepts of algebra (Mengistie, 2020). In junior high school, students learn about how to express the real problem into alge-

braic form using variables and solve the algebraic equation, especially linear equation. Mengistie (2020) said that linear equation be the important topics in algebra and has important role in other mathematics concepts.

In fact, most of students have lack in understanding the concept of linear equation. They have problem in seeing the equal sign. Students view the equal sign as symbol that indicate the answer (Knuth et al., 2006; Tan et al., 2013). For example, when solving the problem $4 + 8 = 5 + \underline{\quad}$, the students put the adding numbers of 8 and 4 in the blank (Falkner et al., 1999).

The fact of lacking understanding of linear equation concept also found at a public junior high school in the province of East Nusa Tenggara (NTT). During an interview with a mathematics teacher who has three years of teaching experience, the teacher mentioned that there are issues regarding the solving of linear equations with one variable in the seventh-grade curriculum, particularly in the operations of addition and subtraction. The problem arises from the students' incomplete understanding of the concept. The students are not aware of the correct fundamental concept of "moving terms."

They mistakenly assume that when terms are moved, pass the equal sign, the mathematical operation will be reversed or in other word "change sides, change sign". The students do not understand that the changing of the operation because of the inverse operation to preserve the equality of equation.

Balance model is one of strategy that most used by teachers to teach the concept of linear equation. Otten *et al.*, (2019) found that from 29 articles were selected in which the balance model was used to teach linear equation solving, the using of balancing model has positive effects on students' understanding in linear equation solving. The use of balance model is suitable for the concept of linear equation because 1) related to the equality concept: both sides of a balance model represent equal value and can be exchanged, this is very suitable for representing the concept of equality, 2) related to the physical experience: maintaining balance as a biological activity can be connected to the abstract idea of maintaining equality in an equation, 3) related to learning through models and representations: balance model can provide an opportunity to semantically and syntactically set a foundation for linear equation solving. Based on 29 articles, only 2 articles that using virtual balance model. While others use physically balance model or drawn balance model.

To teach a concept effectively, teacher can integrate the learning process using technology as a media. But in fact, at a public junior high school in NTT, they have not yet used digital technology-based learning media to enhance the development of teaching materials. According to Jamun (2018), the use of technology has a positive impact on the field of education. When utilized properly, digital technology in education can enhance students' interest, motivation, the quality of

the learning process, and understanding (Hidayat & Khotimah, 2019). Mathigon is one of learning media that can facilitate the understanding of the concept of solving linear equations with one variable. It provides balance model feature that can be accessed by student interactively. As stated on their website, Mathigon - The Mathematical Playground, Mathigon is a website that resembles a mathematical playground to make online learning more engaging and interactive, created using free features. Mathigon offers several features including Polypad, courses, activities, and lessons. Among these features, there are various topics such as geometry, fractions, algebra, and probability. In the algebra section of the Polypad feature, there are illustrations related to balancing scales. Mathigon's Polypad feature can be used to visualize abstract concepts in mathematics. According to Prasetya (2021), Mathigon can be utilized to create digital teaching materials in the form of interactive activities.

To support students' understanding, the learning material must be presented sequentially so that student has a complete comprehension. Therefore, Mathigon must be integrated using other learning media because Mathigon doesn't have features to present it. There are various digital-based learning media available, including e-books, websites, e-modules, flash, and others (Sitepu, 2022). The chosen learning media for this study is a website because it can contain images, links (videos or other required resources), interactive PowerPoint. A website-based learning media is practical and can be accessed anywhere with an internet connection (Aditya, 2018). In line with this, according to Setyadi & Qohar (2017), in their research, they stated that a website-based learning media allows students to actively engage in the learning process. One of the platforms used for creating

websites is Google Sites. According to Pubian & Herpratiwi (2022), Google Sites can be used as a learning media in 21st-century classrooms and the technological industrial revolution. Google Sites is one of the products in Google Docs that is used for creating websites for free.

From the elaboration above, the combination of Google Sites and Mathigon as learning media can assist seventh-grade students in understanding the material of solving linear equations with one variable, especially in the operations of addition and subtraction. This research develops learning media using Google Sites to organize the material effectively. This is in line with the research conducted by Maskar et al., (2021), where the use of Google Sites can help the learning process in creating online notes. The learning media is also combined with Mathigon to make the learning process more interactive. Therefore, the objective of this research is to develop Google Sites as a learning media with the assistance of Mathigon to help seventh-grade students in solving linear equations with one variable using the correct concepts.

METHOD

This research aims to develop learning media based on the needs of the subjects and learning resources to solve the problem about conceptual understanding in solving linear equation in one variable. Therefore, this research utilizes the ADDIE development model (Analyze, Design, Development, Implementation, Evaluation). Because ADDIE development model is a systematically designed model to solve learning problems related to learning resources and learner characteristics (Tegeh et al., 2014). Typically, this research model is used to develop products such as textbooks, learning modules,

multimedia learning materials, and similar materials.

In the analyze phase, a needs analysis regarding what material that still make student confused, what competency that need to be improved, learning environments that are support, and learning media is needed, need to be analyzed. Therefore, at this phase the output produced are profile or characteristics of subjects, identification of needs, and detailed task analysis of learning environments and learning media. The second phase is design. At this phase, a work plan was made by making design principle and story board. While at the third stage, that is development, design that was made at the second stage is realized into the media (Google sites and Mathigon). The media that was made be implemented to the students. This is the results of the fourth phase. For the last phase, evaluation is conducted by giving questionnaire to students and teacher to get the feedback of the implementation of the media in school.

The quantitative data obtained from this research includes the scores obtained from closed-ended questions in the questionnaire to measure validity and practicality, as well as the scores from the learning outcome test. The questionnaire data is measured using a Likert scale. After calculating the average percentage of feasibility and the obtained results in decimal numbers, rounding will be applied. As for the categorization, it is adapted from (Handayani et al., 2021) as shown in Table 1.

Table 1. Criteria for validity and practicality

| Percentage | Criteria |
|-----------------------|---|
| $85\% < x \leq 100\%$ | Very valid/very practical |
| $70\% < x \leq 85\%$ | Sufficiently valid/sufficiently practical |
| $50\% < x \leq 70\%$ | Less valid/less practical |
| $0\% < x \leq 50\%$ | Not valid/not practical |

As for the learning outcome test, a scoring guideline is needed as shown in Table 2.

Table 2. Scoring Guidelines for Learning Outcome Tests

| No. | Indicator | Description | Score |
|-----|---|---|-------|
| 1. | - Presenting concepts in various mathematical representations - Classifying objects according to their specific properties based on the concept | Unable to answer (blank response) | 0 |
| | | Wrong answer and incorrect reasoning | 1 |
| | | Correct answer but incorrect reasoning | 2 |
| 2. | - Restating a concept - Selecting, using, and applying a specific procedure or operation | Unable to answer (blank response) | 0 |
| | | Wrong answer and incorrect reasoning | 1 |
| | | Correct answer but incorrect reasoning | 2 |
| 3. | Determining examples and non-examples of a concept | Correct answer and correct reasoning | 3 |
| | | Unable to answer (blank response) | 0 |
| | | Wrong answer and incorrect reasoning | 1 |
| 4. | - Applying concepts in problem-solving - Selecting, using, and applying a specific procedure or operation - Applying problem-solving concepts or algorithms | Correct answer and correct reasoning | 3 |
| | | Unable to answer (blank response) | 0 |
| | | Able to write in mathematical form but incorrect solution | 1 |
| | | Correct mathematical form and solution but without a conclusion | 2 |
| | | Correct mathematical form, solution, and conclusion | 3 |

RESULTS AND DISCUSSION

Developing Learning Media

Analyze

Adapted from Sugiyono (2013), the analysis phase includes the analysis of the material, competency analysis, learning environment analysis, and analysis of learning media needs. The detailed results of the analysis are as follows: Through interviews with a teacher at a public junior high school in East Nusa Tenggara, it was

found that the students do not understand the basic concept of solving linear equations with one variable. They have been solving equations by moving terms without understanding the basic concept behind it. The teacher mentioned that one of the reasons the students do not grasp the concept is because the language used in the reference book is very advanced and difficult to comprehend. Additionally, the teacher has never used learning media, while according to Novitasari (2016), learning media can assist in the students' concept comprehension.

The school environment is supportive, with features such as Wi-Fi and a projector screen. The students tend to be passive, and so far, the teacher has only used lecture-based teaching methods.

Since the school is still using the 2013 curriculum, the relevant competencies encompassing the material are Competency Standard 3.6, which involves explaining linear equations and inequalities with one variable and their solutions, and Competency Standard 4.6, which involves solving problems related to linear equations and inequalities with one variable. This study focuses on the precise concept of moving terms in addition and subtraction operations because by using the correct steps and solution rules, students can think systematically and accurately as well (Patricia & Laja, 2020).

Design

Based on the analysis of the material, the topic used is solving linear equations with one variable, specifically focusing on addition and subtraction operations. Real-life problems are used as the context for the learning material because. According to Sulastri (2016), Learning that is closely related to students' daily lives can facilitate their understanding of concepts. The required learning media is a medium that

can combine several structured and well-organized real-life problems. A website that created by Google Sites is a suitable learning medium that can combine the created problems, guide students in a structured and easy to use (Jubaidah & Zulkarnain, 2020). There are several features that help make the learning media more structured and have a clear flow, including pages and embeds.

Mathematics becomes meaningful and engaging when learning involves interaction with learning media that visualize basic mathematical concepts. One website that resembles a mathematical playground is Mathigon. Mathigon is chosen because, according to Istiqomah in(Prasetya, 2021), it is an interactive learning media that can be utilized to visualize abstract concepts. One of the tools available in Mathigon that aligns well with the topic is the balance scale in the Polypad feature. This feature is highly relevant to the concept of solving linear equations with one variable. Research conducted by (Wahyuni, 2019) shows that the concept

of linear equations with one variable can be visualized using the concept of a balance scale. Therefore, this learning media will utilize the balance scale feature in Mathigon to teach the solution of linear equations with one variable.

This study will develop a website-based learning media using Google Sites with the assistance of Mathigon. The selected problems will be closely related to the students. Additionally, design principles are needed to ensure that the learning media can achieve its learning objectives. The design principles can be seen in Table 3.

The next activity is to create a storyboard that will be incorporated into the learning media. The storyboard provides an overview of problems that are familiar to the students. The objects used in these problems are local traditional foods, specifically rebok. There will be two problems included in the learning media. The storyboard can be found in Table 4 (See Appendix A).

Table 3. Design principle

| Media Principle | Supporting Principles |
|--|--|
| <p>Learning media needs to provide interactive activities to:</p> <ul style="list-style-type: none"> • Assist students in restating concepts. • Help students articulate the solution process in mathematical form. • Assist students in selecting, using, and applying specific procedures or operations. <p>This is supported by research conducted by Novitasari (2016) which states that interactive multimedia can enhance students' mathematical abilities, encompassing the three indicators mentioned above.</p> | <ul style="list-style-type: none"> • By using Mathigon's Polypad feature, students are asked to move objects to keep the balance on the scale. • By using Mathigon and tables to assist students in writing the solution process systematically. |
| <p>Learning media needs to provide contextual problems so that:</p> <ul style="list-style-type: none"> • Students can determine the unknown objects/elements (variables) in the given problem and the known objects/elements (constants) with their known values. • Students can identify examples and non-examples of a concept. • Students can apply the concept to problem-solving. <p>This is supported by research conducted by Sulastri (2016), which suggests that the implementation of a contextual approach in mathematics instruction can improve students' mathematical abilities, covering the three indicators mentioned above.</p> | <ul style="list-style-type: none"> • Using examples of objects around them, "kompiang", a traditional Manggarai food. • Using contextual problem examples supported by practice exercises on the website. |

Development

The next stage is the creation of a prototype, which involves arranging the previously created visualizations and adding dialogues. The prototype results can be seen in Figure 1 and Figure 2.



Figure 1. Prototype of Problem 1



Figure 2. Prototype of Problem 2

and asking questions to ensure understanding among the students. Once all the components are ready, they can be combined in Google Sites using the "Insert Images" and "Embed" features, linking relevant images. The combined display of the components on Google Sites can be seen in Figure 3.

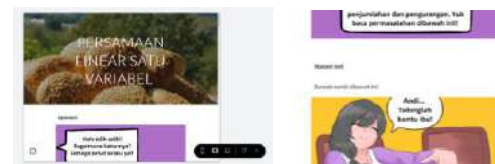


Figure 3. The appearance of Google Sites before the revision.

The next step is validation by experts. The validators in this study are one of the education lecturers from Sanata Dharma University and a mathematics teacher junior high school in East Nusa Tenggara. The results show that the learning media is valid with a percentage of 88.3%, which falls under the category of highly valid.

Revision was made for the first problem. The sentence "berat 1 kotak ditambah 3 kompiang akan sama dengan 10 kompiang" (weight of one box plus three kompiang is equal to ten kompiang) was deemed inappropriate and conveyed a meaning that is not consistent with the concept being taught, according to the validator. Therefore, the sentence was modified to "berat kompiang dalam satu kotak ditambah tiga kompiang akan sama dengan 10 kompiang" (the weight of kompiang in one box plus three kompiang is equal to ten kompiang). Additionally, the content expert suggested the inclusion of assumptions in the concept. The revision was made accordingly, as shown in Figure 4.

Next, create supporting activities such as a preface aimed at recalling previously learned material, followed by a conclusion that includes drawing conclusions



Figure 4. Revision for Problem 1

The validator also provided feedback and suggestions to allow space for participants to write down the process they have done. Therefore, additional space is provided for them to fill in, as shown in figure 5.



Figure 5. Revision for Mathigon

The validator suggested adding a sub-chapter before the main content by maximizing the features available on Google Sites. The "Pages" feature is used to create a more structured presentation and implement the media expert's advice to maximize the features on Google Sites.

The revised version of Google Sites can be seen in Figure 6.



Figure 6. Revision for Google Sites Layout

Implementation

The implementation phase took place on November 19, 2022. The implementation was conducted offline for 3 hours of class or 120 minutes, and it was observed online through a Zoom meeting. During this phase, the quality of the learning learning media was assessed and found to be practical. The practicality was determined based on the questionnaires filled out by the teachers and research subjects. Following that, on November 26, 2022, a learning outcome test was administered consisting of 4 questions and completed individually and in a closed setting. According to Rapono et al., (2019), the learning outcome test can measure the students' abilities, and it was found that 80% of the research subjects achieved scores above the minimum passing grade.

Evaluation

From the implementation results, questionnaires were distributed to the research subjects and teachers. The findings revealed that the teachers felt supported by the learning media that was created. They also believed that the learning media helped the students in understanding the basic concepts of solving linear equations with one variable, particularly addition and subtraction operations. The research subjects also mentioned that using this learning media helped them better

comprehend how to solve linear equations with one variable and gain a deeper understanding of coefficients and variables. One of the advantages of this learning media was its use of objects that were familiar to the students, such as NTT's traditional food, "kompiang," which added contextual relevance to the problem-solving scenarios. This provided an advantage for the students as they could easily comprehend and relate the learning materials to something familiar and relevant in their daily lives.

In conclusion, both teachers and students found the Google Sites learning media with the assistance of Mathigon to be beneficial. Since the students were using Google Sites and Mathigon for the first time, they faced some difficulties in operating the tools, particularly Mathigon. However, these challenges could be overcome with the guidance and support of the teachers.

The Quality of Learning Media

Validity

According to Walker & Hess (1984), the criteria for validity in instructional media include content and objective quality, instructional quality, and technical quality. In the study conducted by Panjaitan *et al.*, (2020), the validation sheet was divided into two parts: a media validation sheet that covers the general technical aspects of instructional media, and a content validation sheet that covers instructional and content aspects. Therefore, in this study, two validation sheets were used: a media validation sheet that assesses the technical quality of instructional media, and a content validation sheet that assesses the content quality, objectives, and instructional quality. The instructional media validator consisted of a mathematics education lecturer from Sanata Dharma University and a mathematics teacher from a

public junior high school in East Nusa Tenggara. Media and content experts completed a questionnaire consisting of 29 closed-ended questions and 8 open-ended questions. The results of the validation questionnaire can be seen in Table 5.

Table 5. The results of the validation questionnaire

| Criteria | Indicator | Val. 1 | Val. 2 |
|--------------------|---|--------|--------|
| Content objectives | Relevance of content to the quality and Basic Competence (KD) | 6 | 8 |
| | Conceptual accuracy | 3 | 4 |
| | Sequence of presenting material | 6 | 8 |
| | Appropriateness of provided examples | 9 | 12 |
| | Appropriateness of language for student thinking level | 3 | 4 |
| | Language fluency | 3 | 4 |
| | Terminology accuracy | 3 | 4 |
| Learning quality | Grammar and spelling accuracy | 3 | 4 |
| | Learning objectives | 7 | 8 |
| | Conceptual understanding | 3 | 4 |
| | Summarization | 3 | 4 |
| | Provision of exercises | 6 | 8 |
| Technical Quality | Appropriateness of illustrations to clarify the material | 4 | 4 |
| | Font | 9 | 12 |
| | Spacing usage | 3 | 4 |
| | Illustrations | 6 | 8 |
| | Navigation buttons | 3 | 4 |
| | Background color | 3 | 4 |
| | Ease of use | 6 | 8 |
| Total | | 89 | 116 |
| Score percentage | | 76,7% | 100% |
| Overall percentage | | 88,3% | |

Val 1 and Val 2 refers to Validator Score for responden 1 and 2.

With an overall percentage of 88.3% and based on the categorization, the instructional media can be classified as highly valid as it meets the minimum threshold for high validity. Both validators also stated that the instructional media can facilitate students' understanding of the concept in solving one-variable linear equations. Regarding the content aspect, the validator provided some suggestions, stating that the concept needs to be adjusted by modifying less appropriate sentences and providing assumptions. These details have been explained further in the development section.

According to the validator, the strengths of the instructional media include using problems that are relatable to students, engaging illustrations and stories, interactive features, and providing detailed explanations of solution steps using language that is easily understood by students. However, the validator mentioned a limitation of the instructional media, which is the underutilization of features in Google Sites. It would be beneficial to provide structured pages or sub-topics for better organization.

Practice

According to Akker et al., (1999), stated that the level of practicality can be observed from the responses of teachers and students in using instructional media, whether they consider the media to be easy and usable. To measure practicality, a questionnaire was used as a research instrument. The results of the questionnaire can be found in Table 6 and Table 7.

Table 6. Results of Students's Practicality Questionnaire

| Aspect | Indicator | Score |
|--------------------------------|---|--------------|
| Ease | Easy to carry around | 22 |
| | User interface is easy to understand | 17 |
| | Practical to use | 18 |
| | Clarity of written statements | 23 |
| | Clarity of text on the media | 22 |
| | Provides a place to provide feedback on technical operation | 23 |
| | Illustrations are easily understood | 21 |
| | Overcomes technical constraints and provides a place to provide feedback on technical operation | 22 |
| Usefulness | The learning media can help improve student understanding | 22 |
| | | |
| Practicality Percentage | | 87,9% |

Table 7. Effectiveness Questionnaire's Results

| Aspect | Indicator | Score |
|--------|---|-------|
| Ease | Easy to carry around | 4 |
| | User interface is easy to understand | 4 |
| | Practical to use | 4 |
| | Clarity of written statements | 4 |
| | Clarity of text on the media | 4 |
| | Provides a place to provide feedback on technical operation | 4 |
| | | |

| | | |
|--------------------------------|---|-------------|
| | Illustrations are easily understood | 4 |
| | Overcomes technical constraints and provides a place to provide feedback on technical operation | 4 |
| Usefulness | The learning media can help improve student understanding | 4 |
| | The learning media can help teach specific topics | 4 |
| Practicality Percentage | | 100% |

Based on the results of both practicality questionnaires, from both students and teachers, the instructional media is considered very practical. The overall percentage is 94%, which meets the minimum criteria for being highly valid. According to Putra (2021), instructional media is considered practical if it fulfills two aspects: ease of use and usefulness. This is consistent with the statements provided by students and teachers, who expressed that they felt assisted in understanding and teaching with the instructional media. They also mentioned that the instructional media was easy to use overall. There were some challenges in operating Mathigon, but they could be overcome with the guidance of the teacher.

Effective

According to Akker et al., (2010), effectiveness refers to the extent to which a product achieves its intended goals. Instructional media is considered effective if it helps students find the correct solutions to one-variable linear equations with the appropriate concepts. This can be observed through the test scores of the students. If 80% of the research subjects achieve scores above the Minimum Mastery Criteria, which is 75, then the instructional media can be considered effective. The results of the learning outcome tests can be seen in Table 8.

Table 8. Test Results of Learning Outcomes

| Indicator of Conceptual Understanding to be Achieved | Test Format | Average score |
|---|-----------------|---------------|
| - Restating a concept | Essay | 2,5 |
| - Selecting, using, and applying a specific procedure or operation | | |
| - Restating a concept | Essay | 3 |
| - Selecting, using, and applying a specific procedure or operation | | |
| - Presenting concepts in various mathematical representations | Multiple choice | 3 |
| - Classifying objects according to specific properties based on the concept | | |
| - Determining examples and non-examples of a concept | Essay | 1 |
| - Applying concepts in problem-solving | Essay | 3 |
| - Selecting, using, and applying a specific procedure or operation | | |

Table 9. Percentage of learning outcomes test

| | Number of students above the minimum passing grade | Number of students below the minimum passing grade |
|--------------------|--|--|
| Number of students | 5 | 1 |
| Percentage | 83,3% | 16,7% |

Since more than 80% of the research subjects obtained scores above the average, the instructional media can be considered effective in assisting students in finding solutions to one-variable linear equations with the correct concept. Therefore, it can be concluded that the Google Sites instructional media with the assistance of Mathigon is effective in facilitating concept understanding.

Discussion

The implementation of the media was carried out for 120 minutes. During the implementation, the researcher observed that the students were enthusiastic about using instructional media. After conducting interviews with the students, it was found that they all remembered the instructional media used and found it easier to understand the concept of finding the solution of one-variable linear equation. This is supported by Aditya (2018) who

stated that the website instructional media helped students understand a concept.

One of feature in Mathigon that support students easier in understanding the concept in finding the solution of single-variable linear equation is tools balance scale polypad. Balance model is an innovative tool that makes algebra easier for students to learn and it is also a powerful tool that can make students more understand about the equations' idea (Waaren & Cooper, 2005). The findings of Otten et al., (2019) strengthen the previous statement, that is balance model very suitable for demonstrating the concept of equality because both sides of a balance model represent equal value and can be exchanged. Besides it, balance model can provide an opportunity to semantically and syntactically set a foundation for linear equation solving. It is in line with the findings of Atteh et al., (2017) that one of advantage of the balance model in teaching linear equation is promoting the view of an equation as an object. Study that conducted by Mengistie (2020) show that balanced model teaching method is an effective means of developing students' understanding of a relational view of the equal sign and its ability to operate equality. Most students use more flexible strategies after do the activities using balancing model.

Table 8 shows that the implementation of the media using balance model in Mathigon integrated Google Site can help students in understanding the concept of equality and in finding the solution of linear equation. It is in line with the results as of the study of Otten et al., (2019). However, this study shows that balance model using Mathigon integrated Google Site not enough to facilitate students' ability in determining the example and non-example of one-variable linear equation. The representation of variables in Mathigon is

limited and not enough representative. If we want to use the representative icon, we must download the icon first. Whereas the icon of variables that available in Mathigon is limited. Therefore, although virtual balance models can be used in teaching the concept of finding the solution of one-variable linear equation, but it is not sufficient to facilitate the representative of variables which resulted it is hard to make the suitable representative of variable in one-variable linear equation.

Through interviews, teachers also felt assisted by the instructional media and found it easier to visualize a concept. Teachers also mentioned that the use of instructional media made students more interested in learning mathematics. This finding is in line with (Lestari, 2018), that is using technology in learning, can give impact in learning. Such as, increase students' learning interest, so that it can make learning process more effective. However, there are limitations; due to device constraints and lack of knowledge about digital instructional media, teachers cannot frequently use this digital-based instructional media.

Implications of Research

The results of this study are expected to provide information to teachers regarding website instructional media and Mathigon as alternative learning tools. The research subjects reported that they found assistance from this learning media, and quantitatively, it has been proven that the learning media is valid, practical, and effective. Furthermore, it is recommended to implement them in higher-level subjects or grade levels. It would also be beneficial if students are allowed to create accounts and log in during Mathigon usage, as this would enable teachers to monitor the students' progress.

Limitation

The limitations of this study include: 1) The instructional media developed is still in the preliminary stage and only covers a subtopic of one-variable linear equations, specifically addition and subtraction operations; 2) Due to time, cost, and resource constraints, the researcher monitored the implementation of the instructional media through online platforms such as Zoom meetings; 3) The students did not have Google accounts, which prevented them from signing up for Mathigon.

CONCLUSION

The instructional media, Google Sites and Mathigon, developed using the ADDIE research and development model, can facilitate students' understanding the concept of equality and in finding the solution of linear equation with one variable, specifically focusing on addition and subtraction operations. The quality of the instructional media is evaluated based on three aspects: validity, practicality, and effectiveness. The instructional media is classified as highly valid with an 88% percentage and highly practical with a 94% percentage. Additionally, the instructional media is deemed effective to increase the students' understanding of equal sign and in solving linear equation, as more than 80% of the research subjects achieved scores above the minimum passing grade. However, not sufficient effective in increase the students' understanding of variable.

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Appendix A of article entitled Developing Google Sites and Mathigon Learning Media to Support Students' Conceptual Understanding in Solving Linear Equations in One Variable

Table 4. Storyboard

| Scene | Visual Description |
|--|---|
| Problem 1 | |
| There is a mother who is cooking, and a child named Anita playing on the terrace. Anita is called by her mother. Mother: "Anita... Please help me!" Anita: "Yes, Mom? How can I help?" Mother: "Your relative from another island will visit us, and I will give him a special food gift from Manggarai, which is kompiang." Mother: "I have prepared the rebok and put them in a box, but I forgot how many rebok are in the box. Earlier, I weighed one box plus 3 kompiang, and it was equal to 10 kompiang. Please help me determine the number of kompiang in the box!" Enter Mathigon | Mother cooking Child approaches the mother Conversations between the mother and child with a pink box on the table containing kompiang |
| There is a scale with one box plus 3 kompiang on the left side and 10 kompiang on the right side. The scale is balanced. There is a plate next to the scale. The student is asked to move the kompiang from the scale to the plate, leaving only one box on the left side and keeping the scale balanced. The student is also asked to write the process in a table and represent it in the form of a linear equation. Through this activity, the student is expected to find the solution to the linear equation in mathematical form. | The scale represents the problem with one box and 3 kompiang on the left side and 10 kompiang on the right side. The scale is balanced. |
| Problem 2 | |
| There is a child who is asked by their mother to deliver kompiang to their neighbor. But before that, the child goes to the bathroom first. Anton: "I will deliver these kompiang to the neighbor as instructed by Mom, but I need to go to the bathroom first" 5 minutes later Anton: "Why is it only this much left?!" There is an empty part and only 24 kompiang left Anton: "It must have been the actions of my younger siblings, Andi, Lana, and Fafa. Let me message Andi." Anton: "You took the kompiang from the dining table, right?!" Andi: "Yes, I took 1, Lana took 3, and Fafa took 2." Anton: "Oh no!! Those were supposed to be given to the neighbor, Andii!! Why did you take them?!" Anton: "Before you took them, how many kompiang were in the box?" Andi: "Oh.. I don't know, sorry)):" Anton: "Oh, okay, I will figure out how many kompiang were originally in the box using the Linear Equation with One Variable that I learned at school" Anton: "Next time, if you want to take someone else's belongings, ask for permission first, okay?!" Andi: "Yes, sorry)):" Enter Mathigon | A child places a box containing kompiang A picture of a closed box on the table An image of the box of kompiang open, but with reduced contents WhatsApp chat |
| There is a scale with a box and number cards (available on tiles) on the left side, which are labeled -3, -2, and -1. On the right side of the scale, there is a number card with the value 24. The student is asked to solve the problem by overlapping the number cards on the scale with other number cards representing kompiang. The student is required to change the number cards on the scale to make it equal to 0, leaving only the box on the left side of the scale while keeping it balanced. The student should write the process on the table and find the solution in mathematical form. | The scale represents the problem with one box and number cards labeled -3, -2, and -1 on the left side, and a number card with a weight of 24 on the right side. The scale is balanced. |



Students' Learning Obstacles in Solving Mathematical Proficiency Tasks: A Hermeneutic Phenomenological Study Focused on Algebra

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Abstract

In the context of linear equations in one variable, students often struggle in basic algebra including variable degrees, variable concepts, coefficients, and constants. However, proficiency in understanding algebraic concepts is significantly lower compared to other areas and skills. As a consequence, this research aimed to explore students' learning obstacles in solving linear equations in one variable in secondary schools based on mathematical proficiency. The research design using the hermeneutic phenomenological approach. This research is a framework of the Didactical Design Research (DDR). DDR is based on two paradigms: the interpretive and the critical paradigms to empower students in the context of generating new knowledge as justified true belief. In this study, the researcher delves into the interpretive paradigm. The research subjects involved 46 seventh-grade secondary school students from five different schools across four distinct provinces in Indonesia. The instruments used were test and non-test. The test was done by giving a diagnostic test about linear equation problems, while interviews used the non-test technique. The study findings revealed that students met three types of obstacles in linear equation material, namely ontogenic, epistemological and didactical obstacle. Ontogenic obstacles occur due to insufficient prerequisite knowledge and cognitive limitations. Epistemological obstacles arise when students' understanding works in certain contexts but fails in others, often due to misinterpretations of algebraic principles. Didactical obstacles emerge when instructional materials or teaching methods are inadequate. Therefore, future research can focus on developing a Didactical Design to reduce this obstacle.

Keywords: Didactical Design Research; Learning obstacles; Mathematical proficiency; Linear equation; Hermeneutic phenomenology.

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Abstrak

Dalam konteks persamaan linear satu variabel, peserta didik sering mengalami kesulitan dalam pembelajaran aljabar, contohnya kesulitan dalam memahami konsep variabel, koefisien, dan konstanta. Selain itu, pemahaman peserta didik terhadap konsep aljabar jauh lebih rendah dibandingkan dengan bidang dan mata pelajaran lainnya. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi hambatan belajar peserta didik dalam menyelesaikan persamaan linear satu variabel di sekolah menengah berdasarkan mathematical proficiency. Desain penelitian ini bersifat kualitatif dengan pendekatan fenomenologi hermeneutik. Penelitian ini merupakan bagian besar dari framework Didactical Design Research (DDR). DDR berpijak pada dua paradigma yaitu paradigma interpretif dan kritis dan bertujuan untuk memandirikan peserta didik dalam konteks menghasilkan pengetahuan baru sebagai pengetahuan yang justified true belief. Dalam penelitian ini, peneliti melakukan pendalaman dalam paradigma interpretif. Subjek penelitian ini yaitu 46 peserta didik kelas VII dari 5 sekolah yang berasal dari empat provinsi yang berbeda di Indonesia. Instrumen yang digunakan adalah tes dan non-tes. Instrumen tes dalam penelitian ini berupa asesmen diagnostik tentang persamaan linear satu variabel untuk mengidentifikasi learning obstacle peserta didik, sedangkan instrumen non-tes terdiri dari pedoman wawancara dengan peserta didik. Hasil penelitian mengungkapkan bahwa peserta didik mengalami tiga jenis hambatan belajar pada materi persamaan linear satu variabel, yaitu hambatan ontogenik, hambatan epistemologis, dan hambatan didaktis. Hambatan ontogenik muncul karena kurangnya pengetahuan dasar dan keterbatasan kognitif. Hambatan epistemologis terjadi ketika pemahaman siswa berhasil dalam konteks tertentu namun gagal jika diaplikasikan kedalam konteks yang berbeda. Hambatan didaktik muncul karena sajab bahan ajar atau metode pengajaran yang tidak memadai. Oleh karena itu, penelitian mendatang direkomendasikan untuk berfokus pada pengembangan Desain Didaktis untuk mengurangi hambatan belajar dalam pembelajaran aljabar.

INTRODUCTION

Mathematics is an essential subject taught at various educational levels, from elementary school to high school and even at the university level (Vilianti et al., 2018). Mathematics is divided into three main subjects: algebra, analysis, and geometry (Suherman et al., 2001). However, algebra stands as the most foundational, particularly at the junior high school level, where it plays a critical role in the development of mathematical skills for future learning (Fardian et al., 2024; Jupri et al., 2014). As part of the 2013 Curriculum, developing strong algebraic skills has been prioritized to ensure students' readiness for more advanced mathematical concepts (Putri, Juandi, & Turmudi, 2024). Despite its importance, students often demonstrate lower proficiency in algebra compared to other areas of mathematics, with particular struggles observed in linear equations (Al-Mutawah et al., 2019).

Algebra is considered a gateway subject for higher education and professional careers in mathematics, yet it is also seen as one of the most challenging areas due to its abstract nature (Thorpe,

2018). Among algebraic topics, linear equations are especially difficult, as they lie at the intersection of arithmetic and symbolic, formal mathematics (Sulastri & Arhasy, 2017). Mastery of linear equations is not only essential for progressing to calculus and statistical analysis but also for understanding nonlinear functions in advanced algebra (Casey, 2015; Nagle & Moore-Russo, 2013). Without a thorough understanding of linear equations, students face difficulties in grasping more complex mathematical concepts, limiting their ability to solve real-world problems and engage in future studies (Jupri et al., 2024; Saraswati et al., 2016).

Despite its importance, students face persistent obstacles in mastering linear equations. One of the most pressing issues is students' difficulty in solving word problems involving linear equations. These problems are complex because they require translating real-world situations into mathematical models, a task that many students find challenging (Khoshaim, 2020; Reynders et al., 2014; Siregar et al., 2022). In particular, identifying the correct variables, operations, and

formulating equations from narrative text poses a significant hurdle, hindering their ability to apply abstract concepts to concrete situations (Nashiru et al., 2018; Putri, Juandi, Turmudi, et al., 2024). Moreover, students often struggle with misconceptions in basic algebra including variable degrees, variable concepts, coefficients, and constants (Makonye, 2015). These misconceptions lead to errors in identifying the general form of linear equations in one variable (Arnawa et al., 2019). Misunderstandings about linear equations often lead to repeated errors and misconceptions, creating a barrier to deeper learning (Yansa et al., 2021).

Despite extensive research on linear equations, there remains a significant gap in understanding the specific learning obstacles students face in secondary education, particularly concerning their mathematical proficiency. A learning obstacle represents a condition that restricts students' acquisition of new knowledge during the learning process, potentially causing difficulties in their learning process (Suryadi, 2019a). The diffusion and acquisition of knowledge are likely to take place within a scientific community setting due to transitions occurring between different institutions (Puspita & Kustiawan, 2024). Learning obstacles can be observed based on the relationship between teacher-student-material (Suryadi, 2023). However, any disruptions in these relationships can contribute to the emergence of learning obstacles. Brousseau (2002) classifies learning obstacles into three categories based on their origins: ontogenic obstacles, didactical obstacles, and epistemological obstacles.

An ontogenic obstacle emerges in the student's cultivation of intellectual capabilities (Utami et al., 2022). Students may experience this obstacle if the problems presented by the teacher have difficulty levels either below the actual ability

or above the potential ability of the students (Bakar et al., 2019). The identification of ontogenic obstacles occurs when there is an imbalance between the learning demands and the mental readiness of the student (Islamiyah et al., 2023). Suryadi (2019b) classifies ontogenic obstacles into three categories: psychological ontogenic obstacles, instrumental ontogenic obstacles, and conceptual ontogenic obstacles.

A didactical obstacle refers to a difficulty in learning that is linked to the instructional stages implemented by the teacher (Prabowo et al., 2022). However, the extent of detail in presenting teaching material can impact the student's learning process (Fardian et al., 2024). Didactical obstacles can be identified when the actual learning process and the theoretically expected content are dissimilar. Since the primary aspect of this obstacle can be observed through the content, stages of material presentation, this obstacle may originate from the teaching materials prepared and implemented by the teacher in the learning process.

An epistemological obstacle represents a difficulty in learning that refers to how students acquire knowledge (Suryadi, 2023). This obstacle is defined by the limited understanding of students related to a specific context of knowledge. Consequently, epistemological obstacles can be identified when students' knowledge of a mathematical object they have learned works well in a specific problem context but is then inappropriately applied to another context. In essence, students have an incomplete understanding of that mathematical object.

Mathematical proficiency is defined as possessing suitable or sufficient mathematics skills, knowledge, or experience (Corrêa & Haslam, 2020; Hendriyanto et al., 2024). Proficiency in mathematics

provides learners with expertise, competence, knowledge, and facility in the subject, facilitating successful learning (Fardian & Dasari, 2023; Findell et al., 2001). Acknowledging a student's starting level and proficiency in specific mathematical content forms the basis for creating successful learning environments (Altarawneh & Marei, 2021). Mathematical proficiency is typically characterized by five strands, namely conceptual understanding, adaptive reasoning, procedural fluency, strategic competence and productive disposition. The five strands serve as a framework for examining the knowledge, skills, abilities, and beliefs essential to mathematical proficiency (Junpeng et al., 2020). It is important to recognize that these strands are interconnected and interdependent, playing a collaborative role in the cultivation of mathematical proficiency (Algarni & Lortie-Forgues, 2023; Yunus et al., 2012). The framework aims to identify the components essential for successful learning in mathematics.

Consequently, this proficiency allows learners to navigate the mathematical challenges encountered in everyday life and supports their continued pursuit of mathematical studies through high school and beyond.

While the literature on learning obstacles in algebra is growing, few studies have focused on the impact of conceptual understanding, adaptive reasoning, and strategic competence in overcoming these barriers (Brousseau, 2002; Findell et al., 2001). Furthermore, much of the existing research fails to provide a comprehensive analysis of how these obstacles relate to students' ability to solve linear equations and apply mathematical reasoning effectively. To further emphasize the importance of this research, the researcher conducted a bibliometric analysis of algebra-related publications over the past five years, as shown in Figure 1.

Figure 1 illustrates that there is no direct connection between linear equations and mathematical proficiency. This

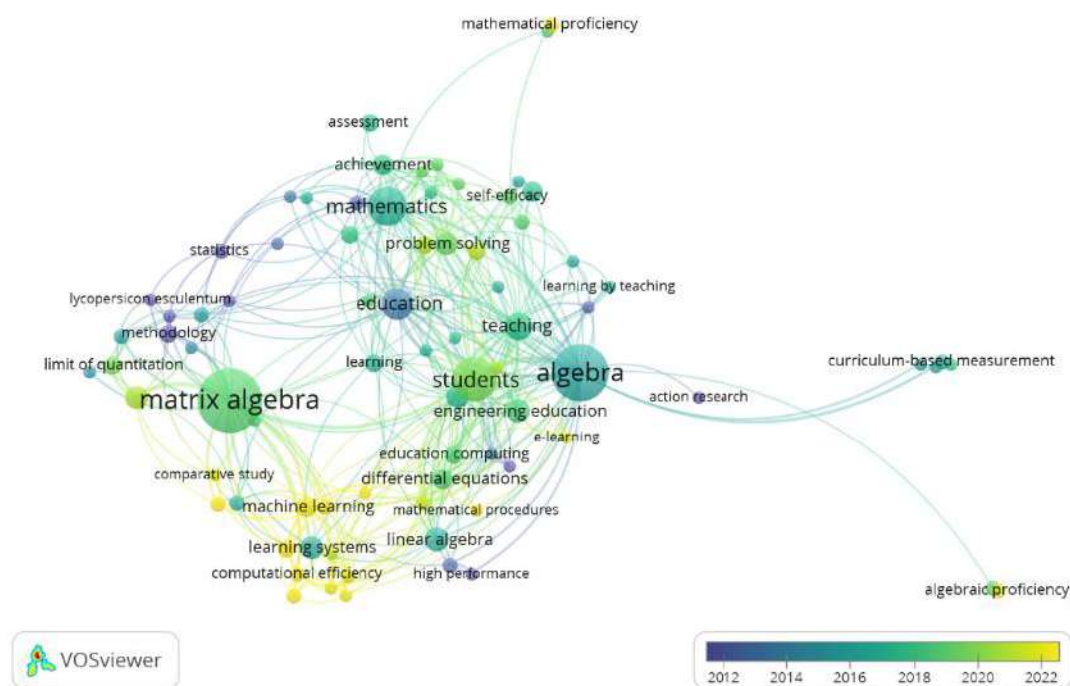


Figure 1. Research trend on algebra over the past five years

suggests a significant research gap in the existing literature. Furthermore, the data shows that mathematical proficiency has been relatively underexplored compared to other topics, as indicated by the smaller number of publications in this area within the bibliometric analysis. The yellow color in the figure highlights that mathematical proficiency has emerged as a hot topic in the last five years, drawing increasing attention from researchers. However, this growing interest contrasts with the limited exploration of its relationship with specific mathematical topics like linear equations, reinforcing the need for further research in this domain.

To provide an overview of previous research on early algebra, Figure 2 summarizes key studies conducted in the field, focusing exclusively on Scopus Q1-indexed articles.

Based on figure 2, the orange nodes in the visualization represent significant

areas of focus in existing research, highlighting the six major themes in early algebra studies. The blue nodes, on the other hand, represent the authors who have contributed to these themes. However, the green node, labeled "Mathematical Proficiency", emphasizes a crucial void in the literature. Despite the extensive focus across the six themes, none explicitly analyzes the role of mathematical proficiency in the context of early algebra. This lack of attention to mathematical proficiency, particularly in relation to key algebraic concepts like linear equations, presents a clear research gap. This focus could pave the way for more effective teaching practices and contribute significantly to mathematics education reform.

The importance of this research is underscored by the findings from the PISA 2022 assessment, which reveal that 61% of OECD countries have mathematics performance below the average, with

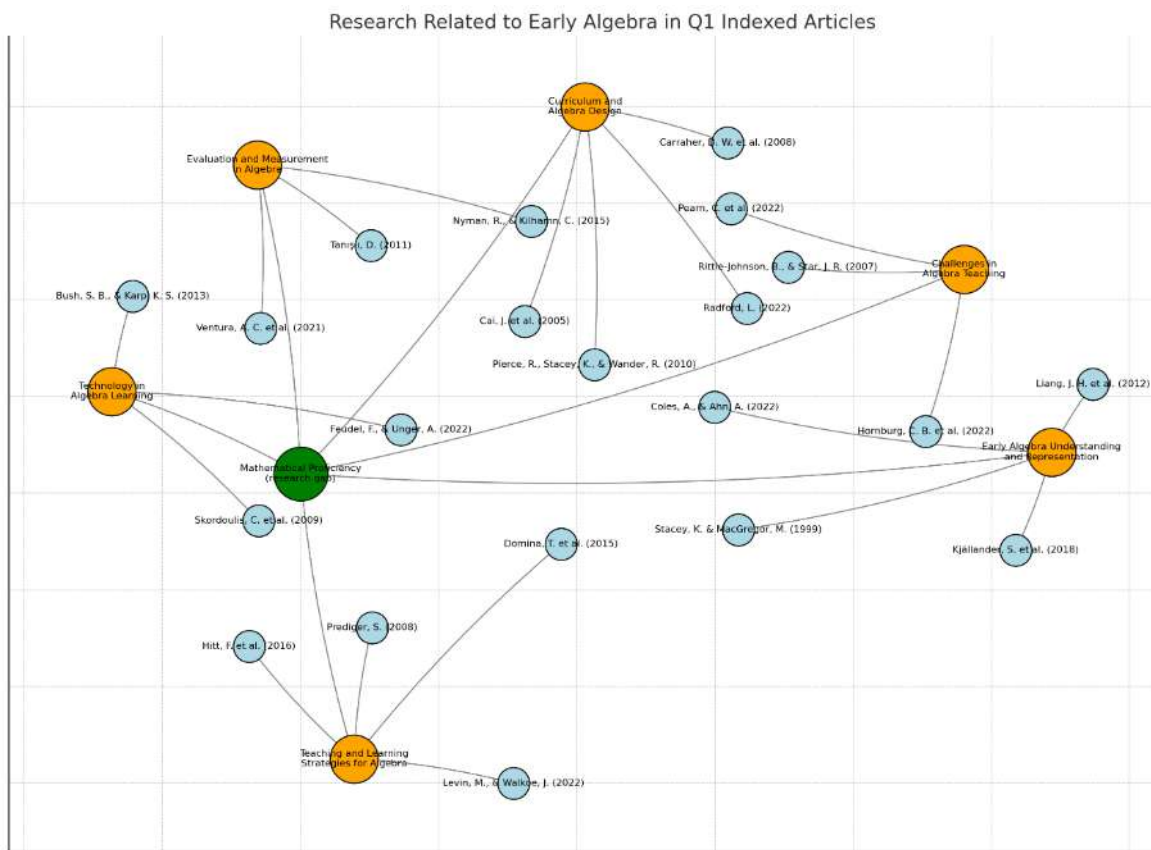


Figure 2. Research related on algebra in the Q1-indexed articles

31% of students demonstrating proficiency below Level 2 (Fardian & Dasari, 2023). This level of proficiency is critical for engaging in active societal participation, making it clear that a substantial portion of students lack the foundational mathematical skills necessary for success in both education and life (Lee *et al.*, 2023).

This study seeks to address this gap by investigating the obstacles students encounter while solving linear equations, emphasizing mathematical proficiency. Through this investigation, we aim to shed light on the specific obstacles that hinder students' progress, including their understanding of basic algebraic principles, their ability to reason adaptively, and their strategic competence in solving real-world problems. By focusing on these critical areas, the research will contribute to a clearer understanding of how these obstacles manifest and how they can be overcome in the classroom.

For this reason, the researcher considers it crucial to identify student learning obstacles in understanding linear equations in terms of mathematical proficiency. Through this identification, it is hoped that it will prompt teachers to establish effective learning environments. This study aims to investigate the challenges that middle school students encounter when solving linear equations.

METHOD

The research design using hermeneutics phenomenological method (Moustakas, 1994). This research is a significant part of the Didactical Design Research (DDR) framework. DDR constitutes research to identify learning difficulties within the educational process, focusing on proactively tackling and eliminating these obstacles (Suryadi & Itoh, 2023). This conceptual framework aligns with the objective of the

current study, which is to explore learning obstacles related to linear equations in secondary schools. DDR is based on two paradigms: the interpretive and the critical paradigms, and it aims to empower students in the context of generating new knowledge as justified true belief (Suryadi, 2019a). In this study, the researcher delves into the interpretive paradigm. The interpretive paradigm aims to analyze the impact of existing didactic designs on students' thinking patterns in the process of acquiring new knowledge, thus identifying learning obstacles.

A total of 46 seventh-grade students were selected as participants, representing five schools across four distinct provinces in Indonesia. The participant distributions are as follows: 7 students from a middle school in West Sulawesi, 24 students from a middle school in Central Sulawesi, 5 students from a middle school in Gorontalo, and 10 students from two middle schools in South Sulawesi. The differences in the selected schools in the research provide important variations in the subjects represented. These schools were chosen with different variations, because: (1) geographical diversity: selecting schools from different provinces allows the research to encompass students from various geographical backgrounds. This can broaden the scope of the research findings and strengthen conclusions about potential learning obstacles. (2) differences in education systems: Each province has slightly different educational approaches, including curriculum, teaching methods, and learning approaches. By selecting schools from various provinces, the research can explore how these differences affect students' understanding and learning, as well as how they influence learning obstacles in the context of linear equations with one variable. Considering these factors, selecting schools from different provinces can help ensure that the

research covers important diversity in the represented student population, thus enabling stronger conclusions about potential learning obstacles in the field of linear equations in one variable. Moreover, the researcher selected for this particular group due to the relevance of the material under investigation to seventh-grade middle school students.

The researchers took several steps

to minimize bias in participant selection and ensure that the sample was representative of the broader population. First, all selected schools were of comparable educational levels, meaning that the schools were chosen based on their similarity in terms of the grade level being studied (seventh-grade) and the overall academic standards. This step was crucial to control for any age-related cognitive

Table 1. The instrument of mathematical proficiency tasks

| Strands | Indicators | Test Instrument | Non-test Instrument |
|-------------------------------|--|---|---|
| Conceptual Understanding (CU) | Unable to solve mathematical concepts | Solve the following equations by writing the steps of the solution: a. $3x - 2 = 10$ | The researcher asks the student to solve the equation $3x - 2 = 10$, explaining each step taken. |
| | Unable to solve mathematical operation | Solve the following equations by writing the steps of the solution: b. $\frac{3x+1}{14} - \frac{1-2x}{2} = 2$ | The researcher asks the student to describe the steps needed to solve the fractional operations in this equation. |
| Adaptive Reasoning (AR) | Unable to think logically about the relationship between concepts and situations | Mirna is 30 years younger than her father. Five years later, the sum of their ages will be 46 years. How old are Mirna and her father now? | The researcher asks the student to read the problem about Mirna and her father, then explain how they use the information in the problem to create an equation. |
| | Unable to justify the conclusions | The price of a chicken is Rp25.000 each, and the price of a goat is Rp700.000 each. Fauzan wants to buy two goats, but he currently only has Rp125.000. To have enough money to buy the two goats, Fauzan decides to sell his chickens. How many chickens does Fauzan need to sell? | The researcher asks the student to justify the steps they took in calculating the number of chickens to sell. |
| Strategic Competence (SC) | Unable to formulate mathematical problems | Risda and Arlinda are running on the same track. Risda runs at a speed of 240 meters per minute and starts 100 meters ahead of Arlinda. If Arlinda runs at a speed of 290 meters per minute, after how many minutes will Risda and Arlinda be at the same position? | The researcher asks the student to read the problem about Risda and Arlinda, then explain how they start formulating the mathematical problem from the given situation. |
| | Unable to represent and solve mathematical problems | After running, Risda goes to buy some drinks. Risda buys 2 bottles of drinks and 2 snacks with Rp50.000 and receives Rp8.000 in change. The price of one bottle of drink is twice the price of one snack. What is the price of one bottle of drink and one snack? | The researcher asks the student to read the problem about the price of drinks and snacks, then explain how they choose variables to represent the price of each item. |

differences that might otherwise influence the results. To further reduce potential bias, the study intentionally included a mix of public and private schools. This strategy was used to account for the variations in resources, teaching methods, and educational systems that may exist between public and private institutions. Additionally, the researchers employed stratified sampling to ensure that the sample was proportionally representative of each region's population. Stratified sampling involves dividing the population into subgroups (regions) and then selecting participants from each subgroup in a way that mirrors the region's actual demographic distribution.

The research employed both test and non-test instruments. The test was done by giving questions about linear equation problems, while interviews used the non-test technique. The current study focuses exclusively on three strands, specifically conceptual understanding, adaptive reasoning, and strategic competence, with several justifications guiding this selection. Firstly, it is important to emphasize that the size and scope of the strands should not be confused, as the model aims to provide a comprehensive depiction of holistic mathematics proficiency strands. Certain strands may hold greater significance at specific age levels than others. For instance, while conceptual understanding and procedural fluency may be fully developed for 14-year-old students, their adaptive reasoning might still be somewhat limited (Findell *et al.*, 2001). Table 1 represent the test and non-test instrument of mathematical proficiency tasks.

Each indicator, category, and code assigned to the student responses are processed using ATLAS.ti 9 software. To mitigate coder bias in the qualitative data analysis, the data coding process is carried out by multiple researchers. This reduces

the risk of individual interpretation errors and ensures consistency across the coding process. Additionally, member checking used to verify the interpretations of student responses, ensuring that the analysis accurately reflects the participants' understanding and experiences. The code label "1A – CU1" indicates the issue found in question 1A (1A), category conceptual understanding (CU), the first code (1), which is "unable to solve mathematical concept.

The data analysis employed in this study used the Miles and Huberman model, which was conducted in three stages: (1) data reduction, where the researchers recorded all student questions responses related to linear equations; (2) data presentation, during which the researchers systematically categorized and identified various types of student responses based on their obstacles; (3) drawing conclusions, wherein the researchers analyzed the identified types of learning obstacles in linear equations among seventh-grade middle school students, drawing insights based on the theoretical framework of learning obstacles (Miles & Huberman, 1994). Figure 3 represents the data analysis process diagram.

RESULTS AND DISCUSSION

Results

The analysis was conducted by examining the components of the obstacle aspect to present the number of students who had obstacles based on the mean score for each set of questions. Subsequently, the analysis progressed to identify the percentage of students facing obstacles in each aspect. The researchers generally observed a uniform distribution of obstacles across conceptual understanding, procedural fluency, and strategic competence.

The result shows that the main obstacles were discovered in the domain of linear equation material, particularly in strategic competence. Strategic competence is the proficiency to formulate, illustrate, and solve mathematical problems (Schulz, 2023). This aspect aligns with what has been termed as problem-solving and problem formulation in the field of mathematics education literature (55.44%), followed by adaptive reasoning, which is the capacity to navigate through a lot of facts, procedures, concepts, and solution methods and discern their interconnected coherence and meaningfulness (48.92%).

Conceptual understanding of linear equation in one variable

On average, 44.57% of students met this initial problem, with a slight standard deviation 5.09. This research indicates that

the data is homogeneous (see table 1). Based on Table 1, most students had difficulties in comprehending and performing operations related to linear equations in one variable.

Table 1. Percentage of students who met indicators on the first obstacle aspect

| Indicators | Question Number | The Number of Students | Percentage |
|--|-----------------|------------------------|------------|
| Unable to solve mathematical concepts | 1a | 7 | 15.21% |
| Unable to solve mathematical operation | 1b | 34 | 73.91% |

To further illustrate the challenges faced by students in solving the problem, Figure 4 provides a visual representation of the patterns of difficulty, particularly in terms of conceptual understanding and performing mathematical operations related to linear equations in one variable.

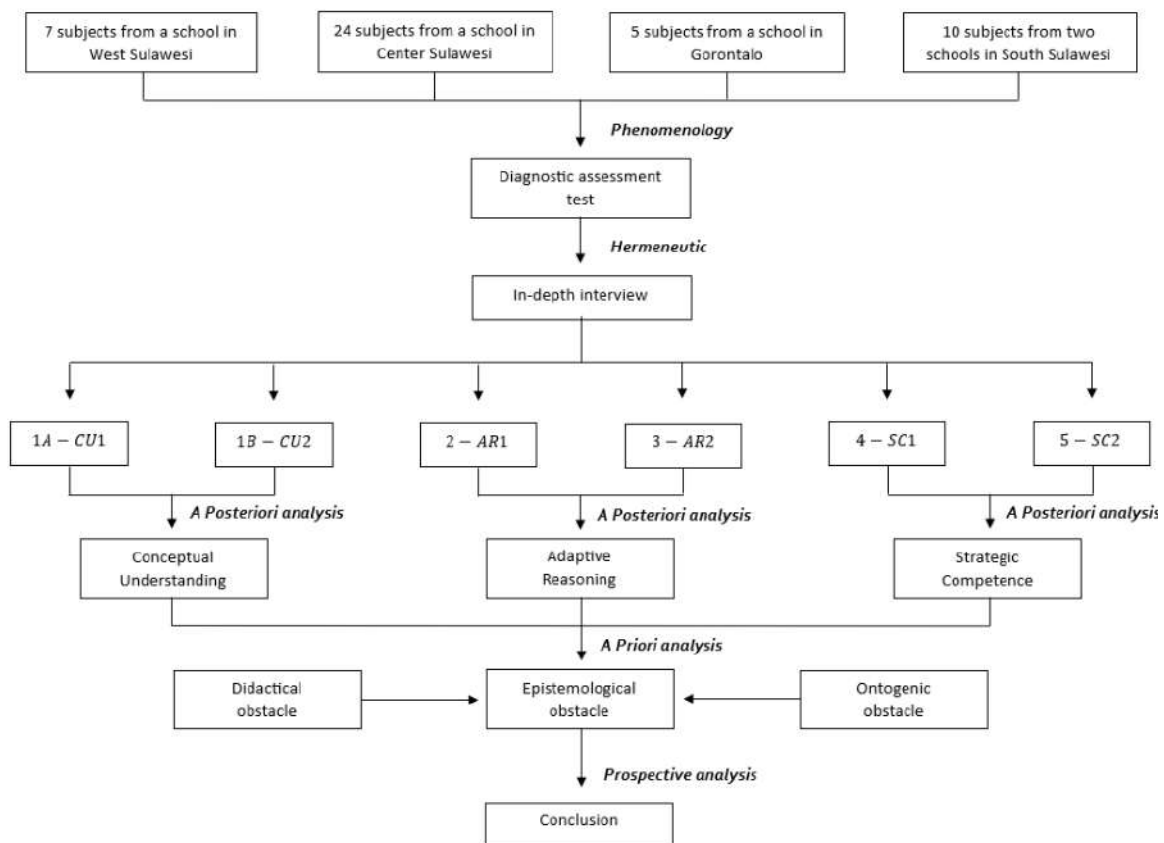


Figure 3. The data analysis process diagram

1.

~~$3x - 2 = 10$~~
 ~~$3x - 2 = 10$~~
 ~~$3x - 2 = 10$~~
 ~~$3x - 2 = 10$~~

$3x - 2 + 2 = 10 + 2$
 $3x = 12$
 $1x = 12 - 3 = 9$

(a)

| | |
|---|-------------------------------|
| 1 | $3x - 2 = 10$ |
| | $3x - 2 + 2 = 10 + 2$ |
| | $3x = 12$ |
| | $\frac{3x}{3} = \frac{12}{3}$ |
| | $1x = 4$ |
| | $x = 4$ |

(b)

Figure 4. Answers by subject 1 (a) and subject 2 (b)

According to the book of seventh-grade mathematics curriculum "Merdeka" developed by the Ministry of Education, Culture, Research and Technology in Indonesia, when solving linear equation problems, students must move terms from one side to the other (transpose). However, there are obstacles experienced by subject 1 and subject 2 (see Figure 1). Subject 1 shifts the coefficient from the left-hand side to the right-hand side, causing the sign in front of the coefficient to change inversely. In 1A – CU1, subject is directed to solve the equation $3x - 2 = 10$. Initially, it appears that the students understand the concept of transposing, which is subtracting the same number from both sides. However, the problem occurs when Subject 1 reaches $3x = 12$, and the student moves the number 3 (red colour) to the other side, resulting in the equation $1x = 12 - 3$.

To examine the underlying meaning behind this student error, the researcher conducted further analysis from a hermeneutic perspective. Hermeneutics, as a methodology, focuses on interpreting and understanding the meaning behind human experiences and actions within

their context. Based on in-depth interview, the error made by subject 1 in transposing the coefficient reflects a misunderstanding of the conceptual framework underlying the operation of moving terms in linear equations. From a hermeneutic standpoint, this error can be seen because of the student's limited contextual knowledge and their inability to fully grasp the deeper implications of the transposing rule. The lack of appropriate examples provided by the teacher, as well as the absence of a comprehensive explanation in the mathematics textbook, means that students may interpret the rule based on surface-level understanding, leading to errors like incorrectly shifting the coefficient without adjusting its sign. Hermeneutic analysis suggests that these kinds of mistakes are not just about cognitive limitations, but about misinterpretations shaped by the absence of meaningful guidance and contextual grounding. Moreover, since one of the sources of this misunderstanding originates from the textbook, the researcher examined the 'Merdeka' curriculum mathematics textbook. Upon review, the researcher found that the textbook presents a mis-interpretation of the concept of transpose, which likely contributes to the students' confusion. Figure 5 illustrates this mis-representation, showing how the textbook may inadvertently encourage a simplistic understanding of transpose, leading students to make errors like the one demonstrated by subject 1.

Students original answer

Kita belajar dari halaman sebelumnya, bahwa dalam persamaan kita dapat memindahkan suku-suku dari satu sisi ke sisi yang lain. Hal ini disebut *mentranspos* atau memindahkan suku-suku.

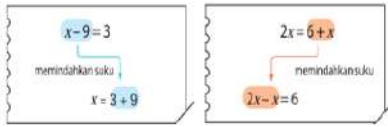
| | |
|--|--|
| $x - 9 = 3$ memindahkan suku $x = 3 + 9$ | $2x = 6 + x$ memindahkan suku $2x - x = 6$ |
|--|--|

Ingat, ketika sebuah suku berpindah sisi, tanda yang ada di depannya berubah menjadi kebalikannya.

(a)

Translation

We learned from the previous page that in an equation, we can move terms from one side to the other. This is called transposing or moving terms.



Remember, when a term moves to the other side, the sign in front of it changes to its opposite

(b)

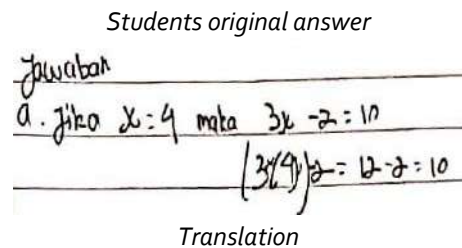
Figure 5. The presentation in the textbook related to the concept of transpose

Based on Figure 5, if students internalize this concept, they will encounter difficulties when they move on to the topic of inequalities. In the concept of inequalities, if both sides are divided by a negative number, the inequality sign will change. For example, $-3x < 12$. If students apply the concept they learned, the inequality will become $x < -4$. However, in the context of inequalities, dividing both sides by a negative number should change the inequality sign, resulting in $x > -4$.

Furthermore, in 1A – CU1, subject 2 selects an arbitrary coefficient and divides both sides by that coefficient rather than dividing by the coefficient associated with x . In the assesment diagnostic test, the student was able to solve the initial problem smoothly and understood the concept of transposing, which involves subtracting the same number from both sides. However, the problem arose when subject 2 reached $3x = 12$. Instead of dividing both sides by the coefficient 3, the student mistakenly divided both sides by 2 (red colour), resulting in the equation $\frac{3}{2}x = \frac{12}{2}$. When researcher asked why the subject 2 divided by 2 instead of the coefficient 3, subject explained that they misunderstood the structure of the equation. Initially, they understood the transposition process, which involves subtracting the same number from both sides. However,

when they reached the equation $3x - 2 = 10$, the student explained that they saw the number 2 (red colour) and mistakenly thought it was the "coefficient" to divide by, rather than the number directly associated with x (which is 3). The obstacle occurs due to the limited understanding regarding the concept of numerical operations and the concept of the coefficient in linear equations.

While Subject 2's misunderstanding stemmed from confusion about the role of coefficients in the equation, subject 3 faced a different type of challenge in solving the problem. Figure 6 illustrates the errors made by subject 3 during this process.



Translation

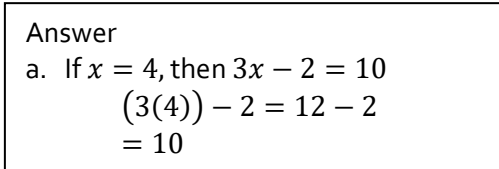


Figure 6. Subject 3's answer

Based on Figure 6, instead of applying a structured approach to isolate x , subject 3 resorted to a trial-and-error method, searching for a value that satisfied the equation without fully understanding the meaning of x in the context of the problem. Subject 3 substituted the value 4 to fulfil the equation $3x - 2 = 10$. Although the chosen number was correct, when the researcher directly asked about the value of x that fulfilled the equation, the students saw confusion in explaining their answer. The student interpreted that the value of x is something that can be replaced with any number without understanding the meaning of x . This led the

subject to use a trial-and-error system, replacing the value of x with any number without considering the equality in the problem.

Based on the hermeneutic analysis, it is revealed that the error experienced by subject 3 stemmed from an inability to distinguish between the concept of the equal sign in algebra and the equal sign in equations. In equations, the equal sign represents a relationship of equivalence between the left and right sides, whereas in algebra, the equal sign is perceived as a command to solve the problem. The student was still operating within an algebraic thinking framework, which was shaped by their previous exposure to algebraic concepts in Chapter 2, before being introduced to equations in Chapter 3. This early learning stage led the student to internalize the concept that the equal sign represents an instruction to solve, rather than recognizing it as a symbol of equivalence that must be respected in the context of solving an equation.

In 1B – CU2, the student experienced difficulties when solving the second problem. Figure 7 represents the student's struggles in this process.

$$\begin{aligned}
 & \text{b. } \frac{3x+1}{14} - \frac{1-2x}{2} = 2 \\
 & \frac{2 \cdot (3x+1) - 14 \cdot (1-2x)}{14 \cdot 2} = 2 \\
 & \frac{6x+2-14+28x}{28} = 2 \\
 & \frac{34x-12}{28} = 2 \\
 & = 56
 \end{aligned}$$

Figure 7. Subject 4's answer

Based on Figure 7, it is evident that the subject has mastered basic arithmetic concepts such as multiplication and division, as evidenced by their responses when solving the initial problem. However, subject 4 encountered difficulties

when reaching the equation $\frac{34x-12}{28} = 2$, where the subject performed cross-multiplication to eliminate the fraction. Despite this, the student was unable to continue solving the equation to completion because they did not understand the technical concept of algebraic manipulation, which made it difficult for the student to fully follow the progression of the learning process. To justify this phenomenon, the researcher conducted an in-depth interview with the subject, as presented in the following interview excerpt

Researcher : I want to ask about question 1b, the problem you previously worked on. The question is $\frac{3x+1}{14} - \frac{1-2x}{2} = 2$. In the first step, what does $2(3x+1)$ mean?

Subject 4 : 2 times $3x$

Researcher : Just 2 times $3x$?

Subject 4 : 2 times $3x$ plus 1

Researcher : Where did you get 2?

Subject 4 : From here (pointing at student work), because it is multiplied

Researcher : Multiplied by what? Why multiplied?

Subject 4 : Because of the cross

Researcher : What? Cross-multiplication, right?

Subject 4 : (silent), because of cross-multiplication

Researcher : Okay, then, so where does this 14 come from? (pointing at student work)

Subject 4 : From here (pointing at student work)

Researcher : Alright, so this 14 is from here, and this 2 (pointing at student work). So, you use a cross-multiply method?

Subject 4 : Yes

Researcher : Okay, so what can be operated on are the ones with the same?

Subject 4 : Like terms

Researcher : Yeah, like terms or those with the same x , right?

Subject 4 : Yes

Researcher : Okay, good job. Now, is the final result 56?

Subject 4 : (silent)

Researcher : Where did you get 56, dear?

Subject 4 : 28 times 2

Researcher : Why is that?

Subject 4 : I don't know anymore

Based on the interview results conducted by the researcher, subject 4 had a learning obstacle. During the phase of moving terms in the form of variables to the left side and terms in the form of numbers to the right side, the subject used cross-multiplication by multiplying the denominators on the left side with the constant on the right side. In other words, subject 4 applied the cross-multiplication method that they acquired in the fraction operation material to linear equation problems. From a hermeneutic perspective, this error can be understood because of the student's previous experiences and the way they interpreted new knowledge based on those experiences. The student's prior knowledge of cross-multiplication in fractions influenced how they approached the linear equation problem. The lack of proper contextual understanding, shaped by their earlier learning experiences, prevented them from interpreting the equation accurately. This error occurred because the student lacked sufficient prerequisite knowledge, which made it difficult to adapt to the process of constructing new knowledge. Additionally, this misunderstanding was also influenced by the teacher's insufficient explanation of the material, which did not provide the necessary clarity for the student to fully grasp the concept.

Adaptive reasoning for linear equation in one variable

In this component, two questions were employed to analyze students' comprehension of the operational procedures for linear equations, featuring two indicators to identify any obstacles in this aspect. The outcomes revealed that, on average, 48.92% of students encountered chal-

lenges in this aspect, with 71.73% of students unable to estimate the results of the problem related to linear equations (see table 2).

Table 2. Percentage of students who met indicators on the second obstacle aspect

| Indicators | Question Number | The Number of Students | Percentage |
|---|-----------------|------------------------|------------|
| Unable to estimate the results of a procedure | 2 | 33 | 71.73% |
| Unable to solve the problem based on procedures | 3 | 12 | 26.08% |

To further illustrate the challenges faced by students in solving the problem, Figure 8 provides a visual representation of the patterns of difficulty, particularly in terms of adaptive reasoning related to linear equations in one variable (2 – AR1).

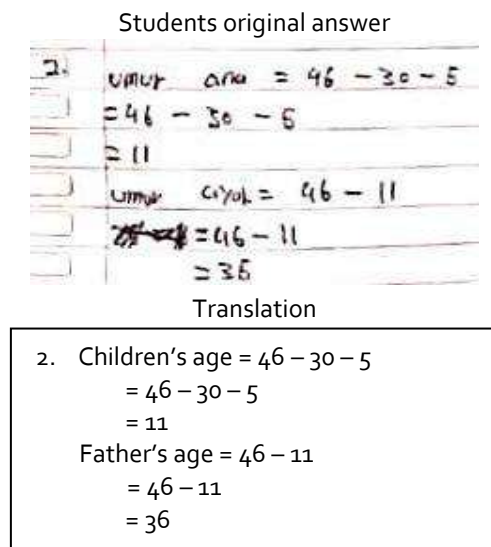


Figure 8. Subject 5's answer

Based on the student's answer in Figure 8, it is evident that subject 5 only interpreted the story problem within the framework of arithmetic thinking without undergoing the process of transforming it into algebraic form first. This was identified because the student did not initially

represent the child's age as x and the father's age as y . The student directly worked through the problem arithmetically. Based on the interview results, it was revealed that this phenomena arose because the problem presented was beyond the student's actual ability, making it difficult for them to solve it correctly. The word problem required the student to apply abstract algebraic thinking, but the student had not yet fully developed the cognitive skills needed for such tasks. As a result, the student struggled to move beyond simple arithmetic operations and was unable to recognize the need to represent the child's age as x and the father's age as y . Additionally, student's struggle and fear of making mistakes when interpreting the information provided in a word problem. The complexity of the problem, combined with the lack of foundational understanding in translating real-world situations into algebraic expressions, led to the student's reliance on arithmetic operations rather than algebraic thinking. This suggests that the student was not able to properly deconstruct and translate the problem into an algebraic form, which is a necessary skill in solving such types of problems. The obstacle indicates that the student's thought pattern remains in the field of arithmetic thinking and has not transitioned to algebraic thinking.

After conducting an in-depth interview, it can be concluded that subject 6 does not understand the meaning of variables in linear equations. This is what causes subject 5 to struggle in transforming word problems into algebraic form. Figure 9 visualizes the errors of student in comprehending the concept of variable.

Students original answer

$$\begin{array}{l}
 2. \text{ } \text{Mirna} + \text{Ayah} = 36 \\
 \text{Ayah} - 30 + \text{Ayah} = 36 \\
 \text{Ayah} + \text{Ayah} = 36 + 30 \\
 2 \text{ Ayah} = 66 \\
 \text{Ayah} = 66 : 2 \quad \text{Jawab} \\
 \text{Ayah} = 33 \quad \text{Jawab}
 \end{array}$$

(a)

Translation

| | |
|----|---------------------|
| 2. | Mirna + Dad = 36 |
| | Dad - 30 + Dad = 30 |
| | Dad + Dad = 30 + 30 |
| | 2 Dad = 66 |
| | Dad = 66 : 2 |
| | Dad = 33 |

(b)

Figure 9. Subject 6's answer

Based on Figure 9, it can be clearly seen that subject 6 interpreted the variables in the problem as "Mirna" and "Father" literally, rather than as symbols representing "Mirna's Age" and "Father's Age." Procedurally, this misinterpretation may not directly affect the student's final answer. However, from an epistemological standpoint, this misunderstanding has the potential to create ambiguity in defining mathematical statements within equations. When students view variables as mere labels or names, they may struggle to recognize them as abstract symbols that represent unknown quantities. Based on the results of the in-depth interview, the subject acknowledged that the concepts they hold are derived from the mathematics book used in the "Kurikulum Merdeka" curriculum, which is applied in classroom learning.

After analyzing the secondary school mathematics book from the Ministry of Education, Culture, Research and Technology in Indonesia for the seventh-grade with the "Merdeka" curriculum, there are obstacles found in the teaching materials prepared and implemented by the teacher in the classroom.

"A rabbit hutch is made from a square fence. Using a wire fence with a length of 24 m, what is the length of the side fence so that the length of the front fence is 3 m longer than the side fence?"

To solve the problem, the first step is to transform the word problem into algebraic form:

$$2x + (x + 3) = 24$$

However, a learning obstacle identified in the secondary school mathematics book from the Ministry of Education, Culture, Research and Technology in Indonesia for the seventh-grade with the "Merdeka" curriculum. In this context, the equation is expressed in the sentence, "two times the side plus the front equals the total length". The equation $2x + (x + 3) = 24$ should ideally be expressed as "two times the length of the side plus the length of the front equals the total length."

Strategic competence in the field of linear equation in one variable

Most obstacles occurred in the material related to linear equations, particularly in strategic competence (55.44%). More than 70% of students could not represent and solve story problems related to linear equations, and approximately 36% struggled to formulate story problems as represent in table 3.

Table 3. Percentage of students who met indicators on the third obstacle aspect

| Indicators | Question Number | The Number of Students | Percentage |
|---|-----------------|------------------------|------------|
| Unable to formulate mathematical problems | 4 | 17 | 36.95% |
| Unable to represent and solve | 5 | 34 | 73.91% |

| Indicators | Question Number | The Number of Students | Percentage |
|-----------------------|-----------------|------------------------|------------|
| mathematical problems | | | |

To further illustrate the challenges faced by students in solving the problem, Figure 10 provides a visual representation of the patterns of difficulty, particularly in terms of strategic competence related to linear equations in one variable (4 – SC1).

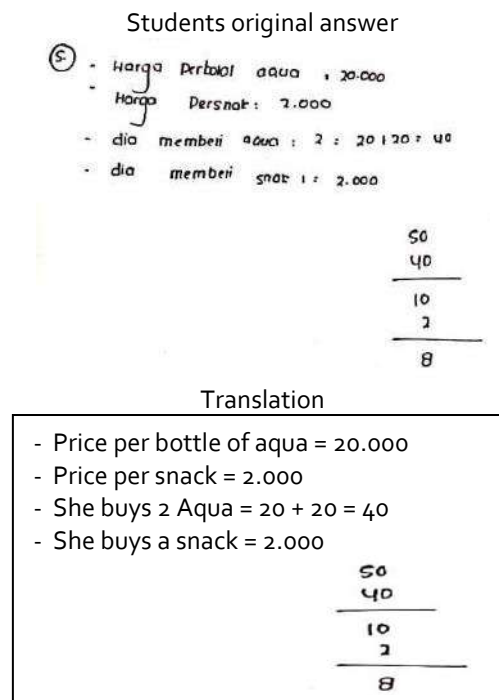


Figure 10. Subject 7's answer

Based on Figure 10, it can be concluded that subject 7 does not understand the sentence "the price of 1 drink bottle is twice that of 1 snack". This misunderstanding occurs due to the limited problem-solving abilities of the student. The inability to properly interpret the relationship between the prices of the drink bottle and the snack suggests that the student struggles with applying mathematical reasoning to real-life situations, which may hinder their ability to solve problems involving ratios or proportional relationships effectively.

Based on in-depth interview, subject's misinterpretation stems from a limited ability to identify and apply key mathematical relationships within the problem. More precisely, the student struggles with proportional reasoning, which is foundational to understanding linear equations. The sentence itself implies a ratio-based relationship (2:1) between the prices of the two items, yet the student either did not grasp this or struggled to translate this into a solvable equation. In other words, many students fail to recognize how to translate real-life situations or verbal descriptions into mathematical relationships. For example, the phrase "the price of 1 drink bottle is twice that of 1 snack" should prompt students to create a simple algebraic expression like $P_{drink} = 2P_{snack}$, but many students do not make this connection. This often happens because word problems involve multiple layers of interpretation that require careful analysis. A lack of number sense can make it difficult for students to connect the verbal description to the mathematical structure. Subject 7's answer, where the price of a drink bottle is assumed to be Rp20.000 and a snack Rp2.000, points to a failure in logical deduction rather than a basic arithmetic error. This suggests that subject 7 may be over-relying on heuristics or assumptions that are not grounded in the problem's structure. For instance, the student may have arbitrarily chosen a set of prices that seem reasonable to them, rather than systematically deriving these from the relationships stated in the problem.

Based on an interview with a teacher, it was revealed that the challenges students encounter in understanding linear equations are not solely attributed to difficulties in applying mathematical concepts but are also influenced by significant disparities in their educational backgrounds. Specifically, some

students, particularly those from elementary schools with more basic curricula, have not been adequately exposed to prerequisite materials, such as the concepts of ratios or proportions, which are essential for a comprehensive understanding of linear equations. As a result, the teacher, being familiar with the characteristics of the students, recommended that the teaching of linear equations should not begin directly with problem-solving tasks. Instead, it is essential to first provide a stimulus, or a review of prerequisite knowledge related to algebra. This approach would help activate students' prior understanding and bridge the gap before introducing more complex concepts, such as linear equations.

Discussion

Mathematical proficiency can be described as possessing the necessary skills, knowledge, or experience in mathematics to a sufficient level (Go, 2023). The strands of mathematical proficiency are referred to as conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Findell et al., 2001). However, the current study focuses exclusively on three strands, specifically conceptual understanding, adaptive reasoning, and strategic competence.

In the conceptual understanding perspective, several phenomena were identified when students studied linear equations. Figure 11 summarizes the overall phenomena and the underlying meanings behind the phenomena identified in students when solving the indicators of conceptual understanding. The white node represents the phenomena identified when students solve problems, while the orange node indicates the meaning behind the identified phenomena (hermeneutic) as students work

through conceptual understanding. The green node denotes the type of learning obstacle encountered during the problem-solving process.

Based on Figure 11, there are six phenomena captured when the subject is working on conceptual understanding tasks. These phenomena included errors made by the students in performing basic arithmetic operations such as addition, subtraction, multiplication, and division. Additionally, students struggled with applying the transpose method correctly, and they found it challenging to recognize patterns or relationships within mathematical expressions. Many students also experienced difficulty with algebraic manipulations, particularly in terms of simplifying or rearranging equations. There was also a limited understanding of the concept of coefficients, and students did not fully comprehend the meaning of the

equal sign in the context of linear equations.

Based on an in-depth investigation from a hermeneutic perspective (Figure 11), it was identified that all phenomenon is caused by seven factors: (1) the subject had weak prerequisite abilities; (2) the presentation of the mathematics textbooks is less comprehensive; (3) the lack of comprehensive examples provided by the teacher; (4) the students' reliance on a trial-and-error method; (5) subject lacked an understanding of the underlying principles of algebraic manipulation (distributive, associative, and commutative properties); (6) subject interprets the "=" sign as an instruction to solve the equation, and (7) subject interprets the concept of transpose as a method of moving terms from one side of the equation to the other.

In the first factor, it was identified

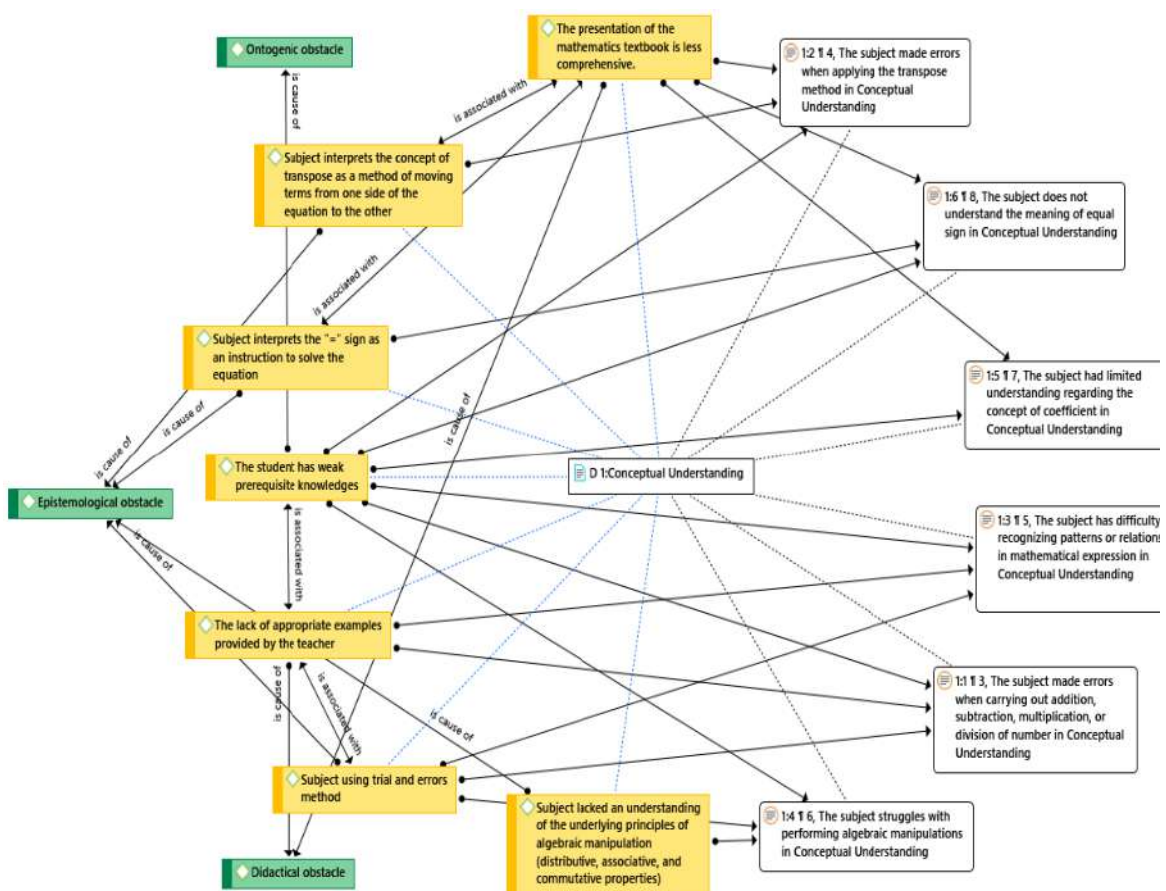


Figure 11. Overall phenomena when students solving the conceptual understanding task

that students have weak prerequisite knowledge related to algebra concepts. According to Brousseau (2002), the mismatch between an individual's cognitive processes and inadequate prerequisite abilities hinders the adaptation of new knowledge, leading to the emergence of ontogenic obstacles. Suryadi (2019b) categorizes these difficulties as conceptual ontogenic obstacles, wherein the conceptual level within didactic design does not align with the students' prior learning experiences. This is in line with Karlsson and Kilborn (2023), which stated that ontogenic obstacles arise when students are unable to connect new concepts to their existing knowledge. Additionally, Utami *et al.* (2023) highlight that such obstacles occur due to students' insufficient understanding of prerequisite concepts, such as variables. Students struggle to make sense of learning due to limitations in their thinking processes (Pratiwi *et al.*, 2019).

The second and third factors reveal that errors arise due to the inadequate presentation of the mathematics textbooks and the insufficient examples provided by the teacher. According to Brousseau (2002), errors resulting from the design of the instructional process or the teacher's interventions are classified as didactical obstacles. This aligns with the study by Hannah *et al.* (2016). When interviewed about the conceptual knowledge they had worked on, some respondents still gave incorrect answers. This suggests that they understand the material better when it is based on examples provided. Consequently, this will likely pose a problem if they encounter different types of mathematical questions. Magfiroh *et al.* (2024) stated that this issue primarily stems from how the textbook content is presented, with insufficient examples limiting students' ability to apply their knowledge in varied contexts.

According to Brousseau (2002), the fourth through seventh factors, namely, the students' reliance on trial-and-error methods, insufficient understanding of algebraic principles (such as the distributive, associative, and commutative properties), misinterpretation of the '=' sign, and misunderstanding of the concept of transpose, can be classified as epistemological obstacles. This epistemological obstacle is identified when students' understanding of a mathematical concept works effectively in a certain context, but when they are faced with a different situation, that understanding becomes difficult or ineffective to apply. These difficulties, however, are not purely the result of external factors but are also linked to ontogenic obstacles, which stem from the students' individual cognitive development and learning experiences. One notable ontogenic obstacle is the students' lack of sufficient prerequisite knowledge. Due to this gap, students often rely on trial-and-error methods to solve problems. This strategy, though sometimes effective in simple contexts, fails when the problem's context changes. The results supported by Pincheira and Alsina (2021), who observed that students often approach algebraic tasks primarily by trial and error, neglecting the structure of the problem and the underlying knowledge required to develop algebraic thinking. Similarly, Edo and Tasik (2022) found that students tend to solve problems based on instinct, trial and error, and logic, rather than relying on a deep understanding of the concepts involved.

From the strands of adaptive reasoning, several key phenomena were observed as students worked on linear equations. Figure 11 provides an overview of these phenomena in relation to the indicators of adaptive reasoning. The white nodes represent the phenomena identi-

fied during problem-solving, while the orange nodes signify the underlying meanings (hermeneutic) associated with students' conceptual understanding. The green nodes highlight the types of learning obstacles encountered throughout the problem-solving process.

Based on Figure 12, four key phenomena were observed as the subject worked on tasks involving adaptive reasoning. First, the subject relied on an arithmetic approach instead of using an algebraic method to solve the problem. This suggests a fundamental difficulty in transitioning from basic arithmetic to more abstract algebraic thinking. Second, the subject displayed a lack of understanding regarding the meaning of a variable, which is crucial for solving algebraic equations. Third, the subject struggled to transform the word problem into an algebraic form, highlighting a challenge in abstracting real-world situations into math-

ematical representations. Finally, the subject tended to focus on procedural steps without grasping the underlying rationale behind them, indicating a reliance on rote procedures rather than developing a deep understanding of the mathematical concepts involved.

Based on an in-depth investigation from a hermeneutic perspective (Figure 12), it was identified that all phenomenon is caused by eight factors: (1) the subject does not understand the concept of equation; (2) the subject interpreted the variables in the problem as "Mirna" and "Father" literally, rather than as symbols representing "Mirna's Age" and "Father's Age"; (3) the available textbook presentation is not comprehensive; (4) the explanation by the teacher is lacking in comprehensiveness; (5) the problem presented was beyond the student's actual ability; (6) the subject's fear of making mistakes when answering questions; (7) previous

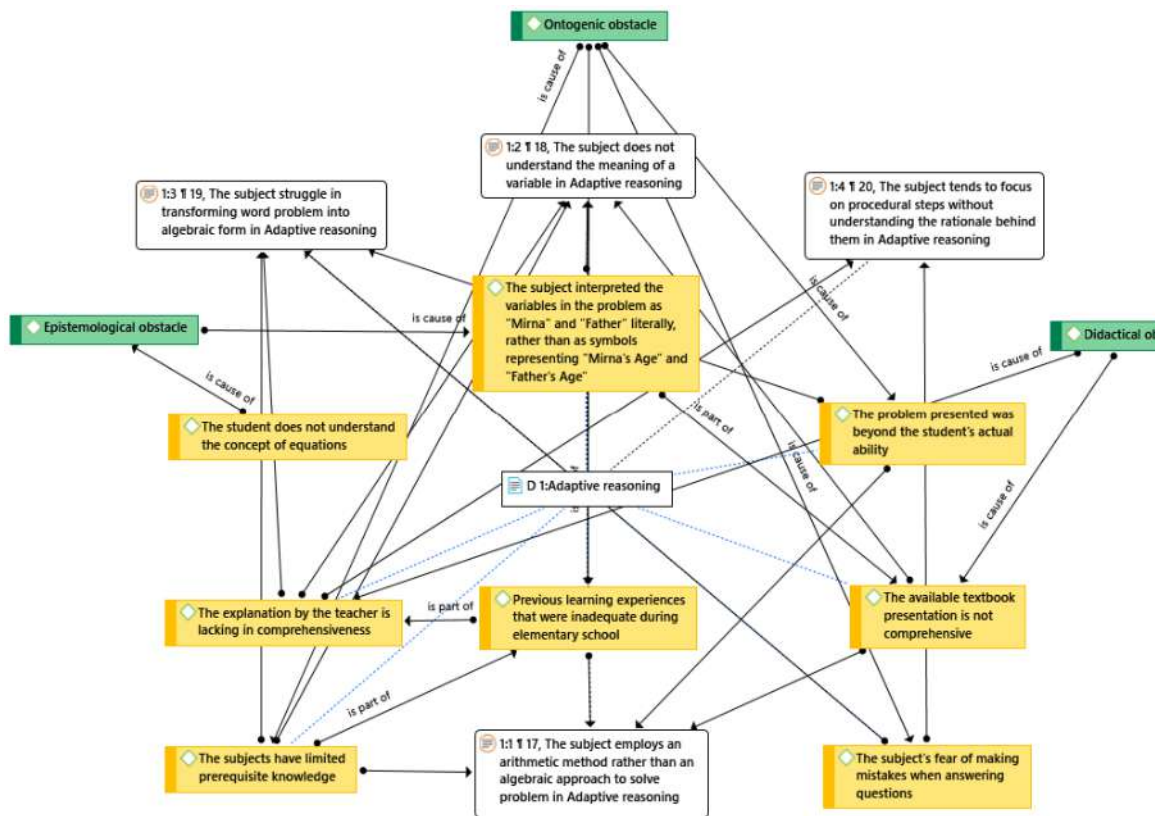


Figure 12. Overall phenomena when students solving the adaptive reasoning task

learning experiences that were inadequate during elementary school, and (8) the subjects have limited prerequisite knowledge.

In the first and second factors, although the students had previously studied linear equations in Chapter III, they failed to apply this knowledge when solving the problem. Instead, they approached the problem from an arithmetic perspective, using basic operations rather than algebraic methods. This reflects a limitation in the students' ability to transfer their understanding to new contexts. While students can solve problems within the same context, they encounter significant obstacles when faced with problems presented in different contexts. Additionally, the students struggled with understanding the concept of variables in equations. According to Brousseau (2002), errors arising from limitations in the context in which a concept is initially learned are classified as epistemological obstacles. These obstacles occur when a student's understanding works well in a specific context but becomes ineffective or difficult to apply in different situations. Li (2010) highlighted that many students' errors and misconceptions arise specifically in areas like variables, equations, and functions, which are foundational to algebraic thinking.

According to Brousseau (2002), errors that result from the design of the instructional process or are caused by an explanation from the teacher that lacks comprehensiveness, as identified in the third and fourth factors, are categorized as didactical obstacles. These obstacles arise when the teaching methods, materials or explanations provided do not fully support the students' understanding or problem-solving abilities, hindering their ability to grasp the concept effectively. Moreover, these didactical obstacles con-

tribute to the emergence of epistemological obstacles for students. The lack of comprehensive material presentation impacts the students' understanding of key concepts, such as equations and variables, preventing them from applying these concepts effectively in problem-solving tasks. This is consistent with the findings of Utami and Prabawanto (2023), who argued that didactical obstacles might be one of the two primary learning obstacles. The second type, epistemological obstacles, occurs when students become confused because the knowledge they have acquired applies only to specific contexts and cannot be transferred to different problems, even though they belong to the same concept. The third type, ontogenic obstacles, is related to the individual development of students and their personal growth in understanding.

The fifth to eighth factors, according to Brousseau (2002), contribute to the emergence of ontogenic obstacles. The complexity of the problem, which exceeded the student's current capabilities, is categorized by Suryadi (2019b) as a conceptual ontogenic obstacle. This type of obstacle occurs when students struggle to understand or apply the underlying concepts needed to solve a problem (Pertwi *et al.*, 2023). The student's fear of making mistakes when responding to questions, as identified in the sixth factor, is classified by Suryadi (2019b) as a psychological ontogenic obstacle. This fear inhibits the student's confidence and ability to approach the problem effectively. Additionally, the inadequate prior learning experiences during elementary school and the limited prerequisite knowledge, prevented the students from grasping the technical aspects of solving the problem. According to Suryadi (2019b), this is categorized as an instrumental ontogenic obstacle, where students lack the necessary skills or techniques to solve the problem

correctly. This aligns with the stages of cognitive development proposed by Piaget (1970), students in the age range of 12-13 years (seventh-grade) are still in the cognitive shift from the concrete operational stage to the formal operational stage. As a consequence of this transition, students may encounter challenges when faced with problems that require abstract reasoning, hypothetical thinking, or the application of formal rules.

In examining the strands of strategic competence, several key phenomena emerged as students worked on tasks involving linear equations. Figure 13 offers a summary of these phenomena in relation to the indicators of strategic competence. The white nodes illustrate the phenomena observed during problem-solving, while the orange nodes represent the deeper meanings (hermeneutic) tied to the students' conceptual understanding. The green nodes indicate the types of learning obstacles that students faced during the process of solving the problems.

Based on Figure 13, three phenomena were identified as the subject engaged in tasks requiring strategic competence. First, the subject struggled to understand the information presented in the problem. Second, subject had difficulty selecting the appropriate methods or

strategies to solve the problems. Lastly, the subject demonstrated limited problem-solving skills, which hindered their ability to effectively tackle the tasks. Based on an in-depth investigation from a hermeneutic perspective (Figure 13), it was identified that all phenomenon is caused by six factors: (1) A lack of student number sense; (2) the subjects have limited prerequisite knowledge; (3) the subject's over-reliance on heuristics or assumptions that are not grounded in the problem's structure; (4) the subject does not understand the sentence "the price of 1 drink bottle is twice that of 1 snack"; (5) the subject struggles with proportional reasoning, and (6) failure of students in logical deduction.

In the first, second and third factors, it is clear that these issues stem from the students' lack of problem-solving skills. This barrier occurs due to technical difficulties, such as a limited understanding of fundamental mathematical concepts or restricted cognitive abilities in breaking down complex problems, which makes it difficult for students to fully keep up with the learning process. According to Brousseau (2002), such mistakes can be categorized as ontogenic obstacles, which are inherent difficulties that arise from the student's own cognitive and developmental limitations in learning. In addition, in the

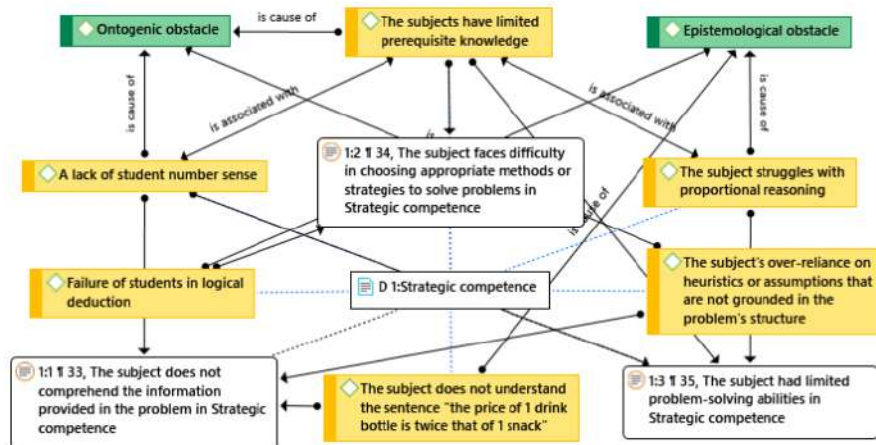


Figure 13. Overall phenomena when students solving the strategic competence task

fourth, fifth, and sixth factors, it is evident that these challenges are attributed to the limited context that students have in their mathematics learning. According to Brousseau (2002), knowledge that was once relevant and effective in specific contexts, including school settings, but later becomes outdated or inadequate, is categorized as epistemological obstacles. This results in line with Swan (2014), which stated that this strand encompasses the capability to formulate, illustrate, and resolve mathematical problem. It aligns with what has been referred to as problem-solving and problem formulation within the field of mathematics education literature. The primary challenge faced by students in strategic competence concerning linear equations is particularly apparent when they attempt to translate information from story problems into mathematical models. However, the results are in line with the research by Astuti *et al* (2017), where students make mistakes when they restate a concept, classify items according to their composition, calculation operations, and apply concepts or problem-solving algorithms.

In summary, the novelty of this study lies in the detailed categorization of learning obstacles (ontogenic, didactical, and epistemological) within the context of linear equations, highlighting both cognitive and psychological obstacles that students face. The research further provides new insights into students' misinterpretations of key algebraic principles, analyzed through the three strands of mathematical proficiency: conceptual understanding, adaptive reasoning, and strategic competence. It also examines how teaching practices can contribute to the emergence of these challenges, offering a nuanced view of the complex factors influencing students' learning. These find-

ings offer valuable implications for educators and researchers, emphasizing the need for more comprehensive textbooks, clearer teacher explanations, and a deeper understanding of cognitive development stages in algebra instruction. By focusing on the foundational knowledge gaps, improving instructional materials and methods, fostering deeper conceptual understanding, supporting students' psychological well-being, and providing appropriate challenges, educators can effectively address the various learning obstacles students face in mastering algebra. These strategies will not only improve students' proficiency in linear equations but also contribute to their overall mathematical development.

Implication of Research

The implications of the findings on learning obstacles can significantly benefit researchers, educators, and policymakers in designing didactic frameworks based on justified true belief. By thoroughly understanding the challenges that students encounter, these stakeholders can develop more effective and precise educational strategies. This, in turn, supports the creation of a learning environment that not only enhances student comprehension and retention but also fosters critical thinking and the application of knowledge. Consequently, this research can lead to a more robust and resilient educational system that is better equipped to meet diverse learner needs and adapt to evolving educational demands.

Limitation

Didactical Design Research relies on two paradigms: the interpretive and the critical paradigms, with the goal of empowering students to generate new knowledge as justified true belief. However, this

study only focuses on the interpretive paradigm. Further research is needed from a critical paradigm perspective to perceptually and memorially examine the learning obstacles identified from previous research results, thus yielding a hypothetical didactic design. Additionally, this research only reveals the potential learning obstacles of learners through the method of hermeneutic phenomenology. Further research is needed on the potential learning obstacles obtained through the analysis of the Theory of Didactic Situations, praxeology, and didactic transposition. Another limitation of this study is that it does not analyze two other strands of mathematical proficiency: procedural fluency and productive disposition. By focusing on only three strands: conceptual understanding, adaptive reasoning, and strategic competence, this research may overlook critical elements of students' mathematical development. Procedural fluency, which involves the ability to perform mathematical operations accurately and efficiently, and productive disposition, which refers to students' attitudes and beliefs about learning mathematics, are both essential in forming a complete picture of students' mathematical proficiency. The exclusion of these strands may limit the overall scope of the findings and their applicability to all areas of mathematical learning.

CONCLUSION

Based on the discussion above, it can be concluded that students identified three types of learning obstacles in linear equation material, namely ontogenic obstacle, epistemological obstacle and didactical obstacle. However, students had limited knowledge, ranging from basic concepts of mathematical operation, arithmetic operations, and solving linear equations in one variable problem.

Ontogenic obstacles occur due to insufficient prerequisite knowledge and cognitive limitations, which prevent students from connecting prior learning to new concepts like variables or algebraic manipulation. Epistemological obstacles arise when students' understanding works in certain contexts but fails in others, often due to misinterpretations of algebraic principles, such as the role of variables or the equal sign. Many students rely on trial-and-error methods instead of developing a deeper understanding of problem-solving strategies, preventing them from effectively transferring knowledge to more complex situations. Didactical obstacles emerge when instructional materials or teaching methods are inadequate. When textbooks are not comprehensive or teachers fail to provide sufficient examples, students struggle to fully understand the concepts, as they lack the necessary support to apply their knowledge effectively. Therefore, it is recommended that teachers construct a Didactical Design to minimize this obstacle.

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2. In writing a bibliography, please use a reference manager, such as Mendeley or EndNote. Citation and bibliography are written in the APA format which has at least 6 references for each keyword in the title. The minimum number of references used is 25 and 80% of them come from international journals.
3. Journal Kreano does not allow articles written by 1 author. This rule have been applicable since 2018 (Vol. 9).
4. There's no numbering in the manuscript.

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1. *Title*

Title is written with clear and concise sentences, consisting of no more than 15 words. Titles are written with the type Capitalize Each Word except for conjunctions in-, for-, and the similar phrases. Title is placed in the middle, single space, Corbel font size 14, in bold. For foreign words, the writing is italicized.

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Name of authors are written in two words (maximum), without academic title. Affiliation could be more than one for an author. Corresponding author only one for each manuscript. Corresponding author is an author who submits the manuscript through OJS.

3. *Abstrak and Abstract*

The abstract begins with a sentence that describes the GAP of your research. Next, the abstract is continued with research objectives, research methods, results, and conclusions. At the end of the abstract, the implications of this research need to be stated. The abstract is written briefly in no more than 150 words for each Indonesian and English. Written in Corbel font size 10pt. Abstract in Bahasa is not necessary for an author from outside of Indonesia. Keywords are written after the abstract using English terms, consisting of 3-5

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4. *Sub-Title*

Section titles are written in capital letters in bold font, for example: **INTRODUCTION, METHOD, RESULT AND DISCUSSION, and CONCLUSION**

5. *Content*

The content is written according to the template. There is no space between paragraphs, but each new paragraph is written 1 cm indented. Writing references or literature, it is enough to write the year without writing the page. Between sections and other sections are given a space of one break. Sub-chapter titles are written in bold italic type. In accordance with instructions no. 4 that the contents of the article consist of:

a. INTRODUCTION

The introduction contains the research background (the story of the phenomena or critical paradigm of the study), theoretical framework, GAP of the study, and ended with a problem statement. The theoretical framework must be justified with the research results. The introduction should be able to explain the contribution of this research in the field.

For theoretical framework references, the editor recommends using primary references, such as Brousseau, Bruner, Vygotsky, Thorndike, etc (Brousseau, 2002b, 2002a; Bruner, 1964; Thorndike, 1914; Vygotsky, 1978). To ensure the novelty of the study, you should compare your research with the research from recent years.

The introduction is as much as 35% of the total length of the text. **3 main things that must be present in the introduction**, namely: (1) **The ideal condition** of learning outcomes in mathematics, or more general form is the dependent variable of a study. Scientific references are needed to strengthen the description of this ideal condition. Usually, government regulations can also be used as references; (2) **The gap** between reality and ideal conditions. In this section, it is better to convey the observation data and researcher's experience in the form of a description; and (3) **Ideas** for minimizing disparities, supplemented by the results of previous related studies.

b. METHOD

This section contains the research methods used. The maximum length of the method is 10% of the entire manuscript if it is **quantitative research** and a maximum of 15% if it is **qualitative research**. The writing method is very dependent on the type of research conducted. In **qualitative research** (*this is highly recommended by the editor*), the writer can describe the focus of the research carried out, whether looking for characteristics of the subject or describing phenomena. In this section, please write down the stages of your research so that the research questions are answered.

In **development research** or **CAR**, the author must write the steps of development and targets at each stage. For example, if your study uses the ADDIE method, you must explain the purpose of each step. If in the Analysis step your purpose is understanding the phenomena, then in the result, you must explain what phenomena happened. Presentation of research stages using a graphic organizer is highly recommended.

The Method is written in paragraphs and divided into 1) participants (and their characteristics such as location, people habit, environment, and culture); 2) instruments; 3) data collection; 4) data analysis. In qualitative research, Editor will ask

the author to maintain what we call the trustworthiness of the qualitative data (Lemon & Hayes, 2020; Stahl & King, 2020).

c. RESULT AND DISCUSSION

In the Result, the author will ask to 1) provide a “big picture” perspective for readers to remind them of the importance of your study and 2) provide a critical analysis of your major finding(s).

The writing of research results depends on the type of research. For **Development Research**, write down all the results of each stage of the research, including if there is a flowchart, write in this section. **Quantitative research** results usually produce tables of statistical analysis results. This section is where the table is presented. The results of **qualitative research** are more flexible. Qualitative research writers can write data reduction, analysis results in each section of research, and findings.

For any findings, please compare them with findings in previous similar studies (references are recommended to scientific journals less than 5 years old), so that the findings of this study are clear, whether corroborating previous research or presenting new findings.

Discussion

This section is an elaboration of the findings written in the results section of the study. In qualitative research, this section describes the meaning of the findings of this study. In quantitative research, this section explains the inference from statistics presented in the results section. In CAR research, this section describes the process of research reflection and a summary of actions that illustrate learning success.

References from related research journals must exist, as part of the state of the art of this research. At the end of the discussion, the author should maintain the novelty of the research. By comparing with previous similar research, the author can place the research position.

Implication of Research

Discuss the implications of your research for pertinent stakeholders (e.g., future research for other investigators, practice suggestions for practitioners, or policy considerations for administrators).

In addressing any of these elements, please make sure your discussion remains directly connected with the study you conducted.

Limitation

Discuss the limitations of the study. These limitations can be organized around simple distinctions of the choices you made in your study regarding who, what, where, when, why, and how.

Limitations of your study can be in the form of the number of research subjects that may not be representative, an unfavorable environmental situation, a sample that cannot be controlled properly, or anything that becomes an obstacle in your research. An explanation of this limitation can be a reason that strengthens your conclusion.

d. CLOSING (CONCLUSSION)

There are several rules of conclusion: 1) Conclusion must be drawn based on research questions and purposes of your study; 2) Conclusion must be a synthesis of key points; 3) Conclusions is written in 1 paragraph.

6. **Figure and Table**

Table and images should not be written more than 3 pieces in each manuscript. Tables and figures need to be provided if referred to in the body of the article. If not referred, it is better not to write tables and figures. For general formulas and tables, there is no need to write them, just write the results.

For example, in the SPSS application results table for the normality test, the homogeneity test, and the average difference test, the table does not need to be displayed, just write the results. For tables or figures, as far as possible write in one column as shown in Table 1 and Figure 1.

Table 1. Sample of Table 1

| | | Levene | df1 | df2 | Sig. |
|------------|-----------------|-----------|-----|-----|------|
| | | Statistic | | | |
| Mid - test | Based on Mean | .449 | 6 | 211 | .845 |
| | Based on Median | .353 | 6 | 211 | .907 |

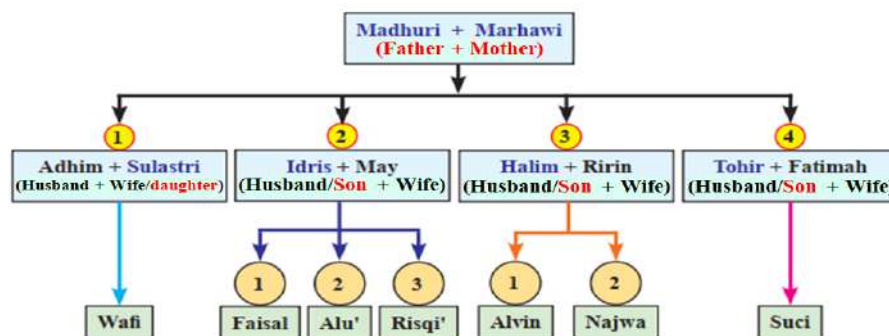


Figure 1. Family Diagram (As'ari, Tohir, Valentino, Imron, & Taufiq, 2017b)

If tables or figures do not allow one column to be written, please use the Text Box, set it to Square in the WRAP TEXT section, and no outline.

7. **Bibliography**

Bibliography is written in APA format, at least 15 references from journals. Each of the keywords in the title, there are 6 references at least.



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