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Additive vs Multiplikatif Thinking: An Exploration of Middle School Students' Proportional Reasoning Ability in Rural Indonesian Context

Filian Yunita Sari[1*], Zulkardi[2], Ratu Ilma Indra Putri[3], Ely Susanti[4]

[1*]Mathematics Education Study Program, Universitas Muhammadiyah OKU Timur
Jalan Tegalrejo, Belitang, South Sumatra, Indonesia
[1*]*filianyunita07@gmail.com*

[2,3,4]Mathematics Education Study Program, Universitas Sriwijaya
Jalan Bukit Baru, Palembang, South Sumatra, Indonesia
[2]*zulkardi@unsri.ac.id*; [3]*ratuilma@unsri.ac.id*; [4]*ely_susanti@fkip.unsri.ac.id*

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Abstrak

Kemampuan penalaran proporsional sangat penting untuk memahami berbagai materi matematika dan menjadi tujuan utama di kurikulum sekolah dasar dan menengah. Penelitian ini bertujuan mengetahui kemampuan siswa SMP dalam bernalar proporsional dalam konteks pedesaan Indonesia. Penelitian kualitatif ini dilakukan pada 33 siswa kelas VII SMP Negeri 1 Belitang dengan menggunakan tes uraian rasio dan proporsi yang mencakup seluruh indikator penalaran proporsional. Hasil analisis menunjukkan bahwa kemampuan siswa dalam bernalar proporsional masih rendah, ditandai dengan tingkat kesalahan menjawab soal lebih dari 87%. Sebagian besar kesalahan terjadi karena siswa menggunakan strategi aditif, bukan strategi multiplikatif yang benar. Temuan ini menunjukkan perlunya peningkatan pembelajaran matematika yang mendukung pengembangan penalaran proporsional, misalnya dengan mengintegrasikan konteks nyata dan aktivitas yang mendorong siswa memahami hubungan multiplikatif secara lebih mendalam.

***Kata Kunci**: Belitang; kemampuan matematika; penalaran proporsional; proporsi; rasio.*

Abstract

Proportional reasoning is essential for understanding various mathematical topics and is a key goal in primary and secondary school curricula. Aims of this research is to identify middle school students' proportional reasoning in rural Indonesia context. This qualitative research was conducted with 33 seventh-grade students at SMP Negeri 1 Belitang using a descriptive test on ratio and proportion that covered all indicators of proportional reasoning. The results show that students' proportional reasoning abilities are still low, with error rates exceeding 87%. Most errors occurred because students used additive strategies instead of the appropriate multiplicative strategies. These findings indicate the need to strengthen mathematics instruction to support the development of proportional reasoning, such as integrating realistic contexts and learning activities that help students better understand multiplicative relationships.

Keywords: Belitang; mathematics ability; proportional reasoning; proportion; ratio.

I. INTRODUCTION

Proportional reasoning abilities are one of the most important goals in the curriculum in grades 5-8 and are needed to understand various mathematical concepts at elementary and middle levels (Izzatin, 2020; Tunç & Çakıroğlu, 2020). Proportional reasoning is a key point in the success of mathematics and science learning in the future (Carney & Hughes, 2015; Khotimi et al., 2024; Sari et al., 2023). Proportional reasoning greatly influences students' mathematical abilities and becomes the standard for students' mathematical proficiency (Sari et al., 2023). Proportional reasoning ability is basic reasoning that is important to understand a lot of mathematical material (Ahmad et al., 2021; Fadilla & Siswono, 2022; Putra et al., 2020; Utari et al., 2015). Various materials in schools that require proportional reasoning abilities include material on comparisons, scales, fractions, decimals, percentages, proportions, algebra, and probability (Astuti et al., 2022; Taufik, 2021; Yuliani & Alfin, 2021). Proportional reasoning is useful for understand many situations in science and the daily lives of future students (Arican, 2019). Proportional reasoning abilities also relate to many real-world contexts such as scaling objects, scaling objects, making good choices when buying goods, exchanging money, unit conversions, recipes and travel planning (Şen et al., 2021).

Proportional reasoning abilities are important, but in fact the development of these abilities varies for each student, there are students who have good proportional reasoning abilities, there are also those who do not (Puspita et al., 2023). Underdeveloped proportional reasoning abilities can cause several problems including errors in understanding learning material, errors in understanding questions, and errors in answering questions (Hudiria et al., 2022). Other facts show that low proportional reasoning among students (Frith & Lloyd, 2016). This is proven by research results Taufik (2021) dan Widayanti et al. (2020) which show that students' proportional reasoning is still not optimal. The low proportional reasoning ability of students is caused by students having difficulty understanding mathematical concepts related to proportionality (Setyaningsih et al., 2018; Taufik, 2021). Arican (2018) research results show that prospective mathematics teachers also have difficulty interpreting and presenting proportional and non-proportional relationships, this is due to inaccurate understanding of basic concepts related to fractions, ratios and proportions.

Proportional reasoning is a mental activity that can determine the relationship between two or more quantities (Prayitno et al., 2019). Then, Wahyuni (2022) defines proportional reasoning as a mental activity that is able to understand the relationship of changes in one quantity to another quantity through multiplicative relationships. Lamon (2012) argues that proportional reasoning involves the ability to recognize and use multiplication relationships to compare quantities and predict the value of one quantity based on another. Proportional reasoning relates to students' ability to understand mathematical forms that are multiplication in comparison (Muttaqin et al., 2017).

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Students who are able to think proportionally have certain characteristics, Wahyuni (2022) and Lamon (2007) explain several characteristics of proportional thinkers, namely (1) have an understanding of covariation, namely understanding the relationship between two quantities varying together and being able to see the suitability of variations from one quantity to another. others, (2) identify proportional and non-proportional relationships in real life, (3) developing many strategies for solving proportions or comparing ratios, mostly based on informal strategies rather than ready-made algorithms, (4) understanding ratios as separate entities that express a relationship that differs from quantities they compare. Then characteristic by Langrall & Swafford (2000) namely 1) relative thinking, namely the ability to analyze changes based on multiplicative relationships, 2) recognize situations when using ratios correctly, 3) understand covariation, 4) form units, ability to use units to solve mathematical problems.

To determine proportional reasoning abilities, one can observe the strategies used by students to solve the proportional problems (Wahyuni, 2022). Proportional problems related with ratio and proportion problems. Chaim et al., (2012) define two strategies for solving proportionally problems, first is formal strategy (using the proportion formula $\frac{a}{b} = \frac{c}{d}; a, b, c, d \neq 0$ and second is the pre-strategy. Formal strategies such as addition, intuition, repeated addition, simplifying comparisons, and finding unit values. Formal strategies are usually used by adults or people with higher cognitive levels, while pre-strategies are strategies commonly used by elementary school students or students with lower cognitive levels (Chaim et al., 2012). Meanwhile, Johar stated that several strategies that are commonly used to solve proportional problems, namely 1) wrong strategies, including calculating without a pattern, determining the difference in solving the problem (additive strategy), equality trial strategy; 2) the correct strategy includes the strategy of replication or repeated addition, the strategy of building up or building gradually by increasing the ratio or reducing the ratio then adding the ratios, the strategy of simplifying the ratio to $1 : m$ where m is an integer, the strategy of changing factors, unit value strategy, equation strategy, and calculation strategy using multiplication or division operations on known quantities (Wahyuni, 2022).

Langrall & Swafford (2000) classify proportional reasoning abilities into four levels, first is Non-proportional Reasoning - Level 0, students cannot recognize multiplicative relationships, use arbitrary number operations and strategies, and cannot connect the two measures; second is Informal reasoning about proportional situations - Level 1, students can use models, pictures or manipulatives to make sense of a proportional situation, and make qualitative comparisons; third is Quantitative Reasoning – Level 2, students can identify or use scale factors or tables and use similar fractions; fourth is Formal proportional reasoning – Level 3, students can use variables in proportions and use

cross multiplication or similarity fraction solving (Wahyuni, 2022).

Based on the explanation above, students' proportional reasoning abilities are crucial for the success of mathematics learning at the primary and secondary levels. There are differences regarding proportional reasoning research, several previous studies focused more on analyzing difficulties and errors rather than assessing students' proportional reasoning abilities (Hudiria et al., 2022; Setyaningsih et al., 2018; Taufik, 2021; Arican, 2018) and other studies focus on proportional problem-solving strategies (Sari et al., 2025a). Apart from that, research related to proportional reasoning abilities has also been carried out in various regions such as South Africa (Frith & Lloyd, 2016); Turkey (Tunç, 2020); and several regions in Indonesia, namely West Java (Taufik, 2021); Pontianak (Widayanti et al., 2020); Karanganyar (Nugraha et al., 2016), but there has been no research that attempts to describe the condition of proportional reasoning abilities of middle school students in Belitang, whether they have the same or different ability conditions. Therefore, the problem formulation is how the proportional reasoning abilities of middle school students in Belitang? With aims of the research is determine the proportional reasoning abilities of middle school students in Belitang. This research will provide new insight into what should be done next, especially related to proportional reasoning abilities and ratio and proportion material.

II. METHOD

The research employed a descriptive qualitative method, focusing on exploring and describing students' proportional reasoning abilities. This research was conducted with 33 students in class VII.3 of SMP Negeri 1 Belitang who were selected using simple random sampling. Colection data by through a comparison and proportion material description test. The test questions given were four questions which contained all indicators of proportional reasoning by Langrall & Swafford (2000). The test questions used in this research adopted questions from the book entitled Proportional Reasoning by Wahyuni (2022) which is valid and reliable. The test result data was then analyzed and several student answers were selected which represented the answers of 33 students who worked on the test questions. Then the researcher presented qualitative descriptive data analysis to find out a picture of the proportional reasoning abilities of middle school students in Belitang.

III. RESULT AND DISCUSSION

A. Results

The research was conducted by administering 4 essay-type questions on proportional reasoning to assess the extent of proportional reasoning abilities in Belitang. The results of the ability test are summarized and presented in Table 1.

Table 1.
Description of Proportional Reasoning Test Results

Indicator	Many students answered the questions

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	Answered correctly	Percentase	Answered wrong	Percentase
Think relatively	3	9%	30	91%
Recognize situations when using ratios correctly	1	3%	32	97%
Understand covariation	4	12%	29	88%
Form a unit	0	0%	33	100%

Refer to Table 1, understood that the majority of students are still wrong in answering proportional reasoning ability questions. Indicators that form units are indicators with the largest percentage of students' errors in answering, namely 100%, followed by students' errors in recognizing situations using ratios correctly at 97%, then the percentage of errors in answering relative thinking indicator questions at 91%, and errors in answering questions with indicators. Understanding covariation has a percentage of 88%.

There are two types of answers where the majority of students experience errors in answering questions about indicators of proportional reasoning ability, recognizing situations of using ratios correctly which are presented in Figure 1 and Figure 2.

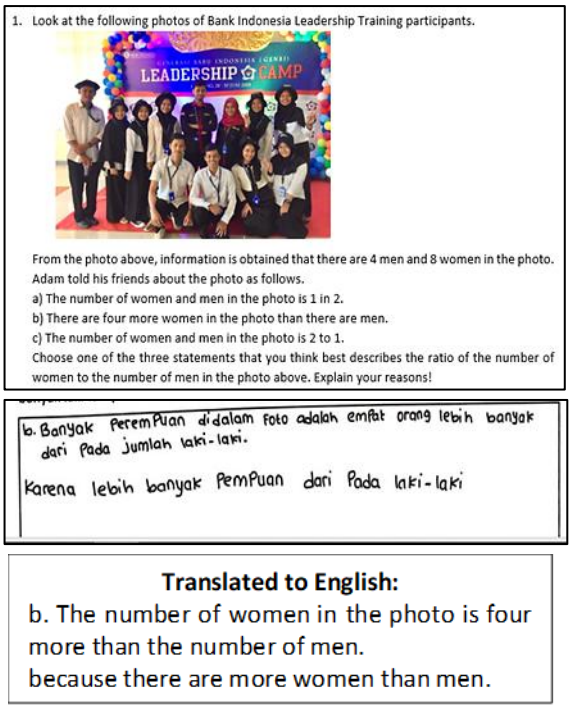


Figure 1. Questions and Sample Answers for S-01 Students.

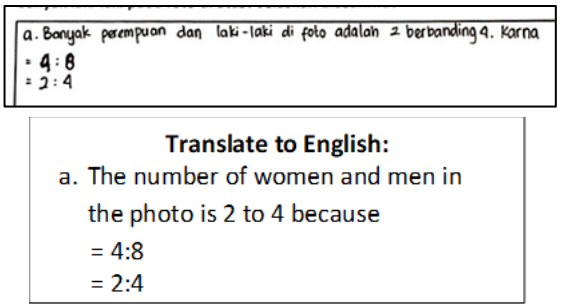
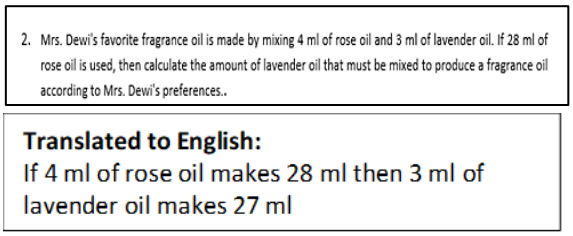


Figure 2. Sample Answers For S-02 Students.

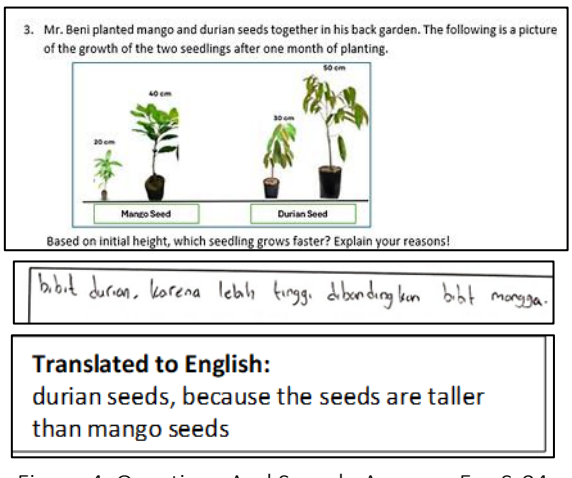
Figure 2 shows that student S-01 answered the ratio situation question incorrectly by focusing on the difference between the number of women and men instead of applying proportional reasoning. In the same figure, student S-02 also gave an incorrect response because the ratio obtained did not correspond to the ratio requested in the problem. Furthermore, most errors related to the indicator of understanding covariation are illustrated in Figure 3.


2. Mrs. Dewi's favorite fragrance oil is made by mixing 4 ml of rose oil and 3 ml of lavender oil. If 28 ml of rose oil is used, then calculate the amount of lavender oil that must be mixed to produce a fragrance oil according to Mrs. Dewi's preferences..

Translated to English:
If 4 ml of rose oil makes 28 ml then 3 ml of lavender oil makes 27 ml

Figure 3. Questions And Sample Answers For S-03 Students.

Figure 3 show that students answered the question incorrectly because they attempted to solve the problem by finding the difference between two values. In the question, the difference between a mixture of rose oil and lavender oil is 1 ml, so if the rose oil is 28 ml then the lavender oil is 27 ml, both have a difference of 1 ml too. This reasoning exemplifies an Additive Strategy, in which students rely on difference-based thinking instead of recognizing that proportional situations require maintaining a constant multiplicative ratio between quantities. Furthermore, the majority of errors in answering questions for the relative thinking indicators are presented in Figure 4.


3. Mr. Beni planted mango and durian seeds together in his back garden. The following is a picture of the growth of the two seedlings after one month of planting.

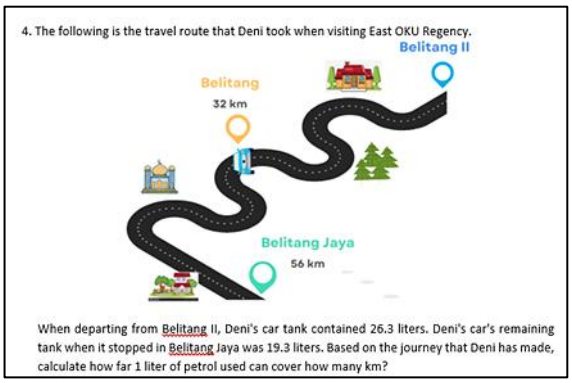
Based on initial height, which seedling grows faster? Explain your reasons!

bibit durian, karena lebih tingg. dibandingkan bibit mangga.

Translated to English:
durian seeds, because the seeds are taller than mango seeds

Figure 4. Questions And Sample Answers For S-04 Students.

In Figure 4, it can be observed that the student S-04 answered the question incorrectly because they were working on proportional reasoning questions by calculating the difference, not by calculating how many times the seeds grew compared to their initial height when planted. The error was due to the use of an additive strategy. As for students' errors in answering proportional reasoning test questions with indicators forming units, it can be seen in Figure 5.


4. The following is the travel route that Deni took when visiting East OKU Regency.

When departing from Belitang II, Deni's car tank contained 26.3 liters. Deni's car's remaining tank when it stopped in Belitang Jaya was 19.3 liters. Based on the journey that Deni has made, calculate how far 1 liter of petrol used can cover how many km?

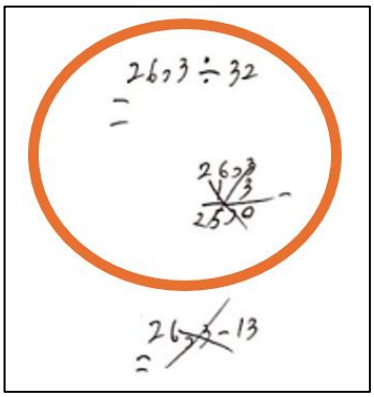


Figure 5. Questions And Sample Answers For S-05 Students.

As shown in Figure 5, before arriving at the correct answer, students attempted to solve the problem by dividing the initial number of car fuel tanks by the distance at which the car stopped. This indicates that the students did not approach the problem in accordance with its intended proportional structure. This error represents an Incomplete Strategy, in which students recognized that a multiplicative relationship was required but applied an incorrect operation or failed to maintain a consistent ratio throughout the solution process.

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B. Discussion

The result test administered to 33 students from class VII.3 at SMP Negeri 1 Belitang, it was found that more than 87% of students were wrong in doing the proportional reasoning ability test questions. This indicates that students proportional reasoning in Belitang is relatively low based on the high percentage of students' errors in answering proportional reasoning ability test questions. This finding accordance with Taufik (2021) and Widayanti et al. (2020) also found that junior high school students' proportional reasoning abilities remain relatively low. Therefore, more attention needs to be paid to proportional reasoning abilities considering the important role of students' proportional reasoning abilities for student in elementary stage (SD-SMP). This aligns with curriculum and evaluation standards in NCTM, which emphasize that proportional reasoning ability is a central concept connecting numerous mathematics topics covered in class 6-8. Therefore, significant time and effort should be dedicated to fostering its development thoroughly (Chaim et al., 2012; Maulandani & Afriansyah, 2024).

From the analysis of students' test answers on each indicator of proportional reasoning ability, it was revealed that students tend to think additively, not multiplicatively. The test results clearly demonstrate that the number of students who answered proportional reasoning questions incorrectly because they used an additive strategy was more than 28 students (see Table 1). This causes the problem solving steps to be wrong and the answers obtained are also wrong. So the majority of students cannot answer proportional reasoning ability test questions correctly. The use of the additive strategy is in accordance with Gea et al. (2023) opinion that the first strategy for comparing is addition. The findings of this study are consistent with Nugraha et al. (2016), who reported that Grade VII junior high school students' errors in solving proportional reasoning problems stemmed from a tendency to apply additive reasoning instead of multiplicative reasoning. Similarly, this result aligns with Nur and Sari (2022), who found that students predominantly relied on additive strategies rather than multiplicative approaches when addressing proportional reasoning tasks.

The dominance of the addition strategy may be due to the fact that in elementary mathematics, students are often exposed to repetitive exercises in addition and subtraction, while multiplication is often introduced as repeated addition rather than as a concept of multiplication or scaling. This approach to learning can weaken students' understanding of multiplication, so that they tend to rely on addition reasoning when solving proportional problems. International studies by Petit et al., (2020) and Tunç, (2020) describe this phenomenon as the "addition trap," in which students incorrectly apply addition strategies to proportional situations. This shows that this difficulty is universal, not specific to Indonesian students.

To overcome the weaknesses identified based on results, it is necessary to change

the teaching strategy in ratio and proportion material which focuses on increasing proportional reasoning abilities. Teaching strategies that can be used as alternative choices include using a realistic approach in learning mathematics. Many recent studies use realistic approaches that have proven successful in helping students learn mathematics. Like research by Sari et al., (2024) which was successful in helping students' understanding of ratios using the cooking rice. The use of the realistic context of a Bukit Sulap based on the research of Adha et al., (2024) helps understanding students' concepts of the surface area of blocks and cubes. The use of realistic contexts also helps students understand, develop strategies, and solve mathematical problems (Adha & Putri, 2024). Several recent studies also show the positive impact of using real-world contexts in mathematics learning, such as research using agricultural contexts for ratio material (Sari, et al., 2025b), using the context of plowing fields for rate (Sari, et al., 2025c), and using the context of exploring field size to understand scale material (Sari, et al., 2025d). Several previous studies based on the researchers suggested that learning proportion ratios in the future should focus more on improving proportional reasoning abilities by integrating realistic contexts in learning.

IV. CONCLUSION

The result indicate that the proportional reasoning ability of middle school students in Belitang is relatively low, with an error rate exceeding 87%. Most students relied on additive strategies rather than multiplicative reasoning, reflecting a limited understanding of proportional relationships that may hinder learning of more advanced mathematical concepts. To address this issue, instruction should explicitly emphasize multiplicative thinking by engaging students in realistic contexts and structured tasks that highlight invariant ratios. Teachers are encouraged to use counter-examples that demonstrate the failure of additive reasoning, employ ratio tables and double number lines as reasoning tools, and facilitate discussions contrasting additive and multiplicative strategies.

This study contributes to mathematics education by providing empirical evidence of proportional reasoning difficulties in ratio proportion. However, the findings are limited by the small sample size and single-site setting. Future research should examine targeted instructional interventions, conduct longitudinal studies to track conceptual development, and involve multiple sites to strengthen the generalizability of the results.

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AUTHOR'S BIOGRAPHY

Filian Yunita Sari, M.Pd.

Born in Palembang, 7 June 1999. Currently works as a lecturer in Mathematics Education at Universitas Muhammadiyah OKU Timur, Palembang, South Sumatra. Starting his lecturer career in 2023. He graduated with a bachelor's degree in Mathematics Education at UIN Raden Intan Lampung in 2021, a master's degree in Mathematics Education at Semarang State University and graduated in 2023. Currently, she is continuing his doctoral studies in Mathematics Education at Sriwijaya University since 2023.

Prof. Dr. Zulkardi, M.I Kom., M.Sc.

Professor of Mathematics Education at Sriwijaya University (UNSRI) Palembang. He completed his undergraduate studies in Mathematics Education at Sriwijaya University in 1984, Masters in Computer Science at the University of Indonesia Sandwich with University of Maryland, USA in 1990, Masters in Science at the University of Twente, the Netherlands in 1999 and PhD in Mathematics Education at the University of Twente and the Freudenthal Institute University of Utecht, the Netherlands in 2002.

Prof. Dr. Ratu Ilma Indra Putri, M.Si.

Professor in mathematics education at Sriwijaya University. He completed a Bachelor's degree in Mathematics Education at Sriwijaya University in 1991, a Master's Degree in Statistics at IPB in 1999, and a Doctoral Degree in Research and Evaluation in 2010. He also attended a post-doc for 4 months at the Freudenthal Institute, Utrecht University and attended a session school on design research at Jaen University, Spain.

Dr. Ely Susanti, M.Pd.

A mathematics education lecturer at Sriwijaya University who has expertise in calculus and Real Analysis. In 2002, he completed his undergraduate studies at Sriwijaya University. In 2009, he completed his Master's studies at Sriwijaya University. Has completed his PhD at the Indonesian University of Education.