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Identifying Field-Independent Cognitive Styles of Junior High School Students on Numeracy

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Abstract: Numeracy encompasses not only the manipulation of numbers and their operations, but also the application of concepts, procedures, facts, and mathematical tools to problem solving. In numeracy, there are cognitive levels that form a hierarchy of thinking, which includes knowing, applying, and reasoning. The cognitive level of reasoning involves the process of formulating problems, using mathematical concepts or procedures, and interpreting solutions in real-life contexts. To reach this level, analytical thinking is required, as FI individuals have a tendency to organize unorganized objects and vice versa. This research aims to describe how FI students use their numeracy skills to solve social arithmetic problems that arise in daily life at each cognitive numeracy level. A case study design was chosen as an alternative to achieve research objectives. Data collection was carried out using test-based interviews. Students are given two stimuli related to ratios and percentages, with each stimulus having three questions adjusted to the cognitive level of numeracy and followed by an interview. The data is then reduced and presented until valid conclusions are obtained based on data saturation. The results of the research show that FI students are able to identify known things related to ratios/percentages and explain the concept of ratios/percentages in solving social arithmetic problems. They are able to create mathematical models and apply these models to solve social arithmetic problems, provided that they pay more attention to writing down the solution steps to minimize writing errors. FI students can draw conclusions based on ratio/percentage information and provide arguments to support claims related to ratios/percentages in solving social arithmetic problems. If FI students remember to always use notation, the conclusions they draw will be correct. The research's three FI students met the indicators, but there are a few points that need further emphasis.

Keywords: numeracy, cognitive level, field-independent, ratio and proportion.

▪ INTRODUCTION

Obtaining numeracy, or what could also be called mathematical literacy, is the human right of every individual (Geiger & Schmid, 2024; Goos, Geiger, & Dole, 2014; Huntington, Goulding, & Pitchford, 2023; Pugalee, 1999). The importance of numeracy prepares individuals to face the challenges of the 21st century, so every individual must master it (Díez-Palomar, Ramis-Salas, Močnik, Simonič, & Hoogland, 2023; French, 2013). Aside from that, the importance of numeracy can also help individuals recognize the role of mathematics in the world and make judgments and decisions (OECD, 2018). Every individual living in society has the human right to possess various abilities, including numeracy skills, to meet future challenges and understand the significance of mathematics in daily life.

According to international studies, PISA, show that Indonesia experienced a decline in its numeracy score from 379 in 2018 to 366 in 2022, and this result is among the lowest (OECD, 2023). On a national scale, numeracy is measured through the Minimum Competency Assessment program, which is organized by the state and is mainly carried out for students in grades 5th elementary school, 8th middle school, and 11th high school (Pusmenjar, 2021). Minimum Competency Assessment is a national assessment

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instrument that has replaced national exams since 2021 and is used as a source of information to map and evaluate the quality of the education system (Widarti, Rokhim, Septiani, & Dzikrulloh, 2022). The results of the Minimum Competency Assessment program can be accessed by the public via the educational report card website. In 2021, the Minimum Competency Assessment results show the number of junior high school students in Indonesia whose status is below minimum competency (Rapor Pendidikan Indonesia 2022, 2022). Until 2022, the numeracy of junior high school students in Indonesia will be the lowest achievement among other achievements (Rapor Pendidikan Indonesia 2023, 2023).

Several researchers have conducted research to look for alternatives or significant factors in individual numeracy (Coffey & Sharpe, 2023; Molina-Muñoz, Contreras-García, & Molina-Portillo, 2023; Rachmani & Farah, 2023), and several studies have been conducted to explore student numeracy from various researchers' perspectives (Ekawati, Susanti, & Chen, 2020; Escudero, Lago, & Dopico, 2022; Kolar & Hodnik, 2021). Research by Escudero et al., (2022) explores individual numeracy based on gender, and the overall results show that there are no differences in how numeracy is used by different genders. Further research, including children's performance on nonroutine tasks has described in detail how these individuals use numeracy. Kolar & Hodnik (2021)'s research discusses numeracy in relation to mathematical knowledge and problems, about how sixth grade elementary school students solve non-contextual and contextual problems involving mathematical content. More specifically, research by Ekawati, Susanti, & Chen (2020) also examined students' numeracy based on the mathematical literacy process: formulate, employ, and interpret, and focused on geometry and measurement content. Research that explores student numeracy in more detail is still limited, and there is no research that examines numeracy from the perspective of Indonesia's Minimum Competency Assessment, so there is a need for new research that explores numeracy using indicators that have been formulated by the state.

Several alternatives have been formulated to overcome deficiencies that occur in students' numeracy abilities. Differentiated learning is one of the government's solutions for meeting individual learning needs according to their needs and abilities without imposing the teacher's will on students (Langelaan, Gaikhorst, Smets, & Oostdam, 2024). Teachers can facilitate students based on their cognitive style, aiming to maximize their learning achievement, including their numeracy abilities. Apart from that, looking for factors or exploring numeracy skills is expected to provide teachers with an idea of how to educate their students so that they can correct existing deficiencies. (Höfer & Beckmann, 2009) looked for supporters of numeracy, which was implemented in several schools in Europe. This support is believed to be appropriate for the culture of European students. To achieve similar opportunities to support student numeracy in Indonesia, we need a clearer picture of current Indonesian students, particularly when viewed from the cognitive level of numeracy, which includes knowledge, application, and reasoning.

To solve problems involving mathematical content, Minimum Competency Assessment requires students to use various cognitive levels, namely knowing, applying, and reasoning (Purnomo et al., 2022). Knowing the cognitive level of numeracy allows you to identify students' knowledge about mathematical objects, their applications, and reasoning. Of course, each individual's use of cognitive levels is different, and this can be caused by their cognitive style (Kozhevnikov, Evans, & Kosslyn, 2014; Riding, Glass, &

Douglas, 1993). The cognitive style is a consistent characteristic of an individual that can become a habit (Acero-Mondragon & Tuta-Quintero, 2023; Pantaleon, Payong, Sugiarti, Tamur, & Tato, 2023; Witkin, Moore, Goodenough, & Cox, 1977).

It is called a style and not an ability because it refers to how a person processes information and solves problems, not the best solution process (Uno, 2008). (Witkin et al., 1977) explain that analytical individuals are individuals who perceive the environment into its components, are less dependent on the environment or less influenced by the environment, and are individuals with a field-independent cognitive style (henceforth it will be written as FI). Apart from FI, there are also individuals with a cognitive style that is influenced by the environment and is called field-dependent. Even though there are two groups of different cognitive styles, it cannot be said that FI individuals are better than field-dependent individuals, or vice versa. Individuals who are FI are good at identifying objects or details that have surroundings that might obscure their view (Zhang, 2004). They can sort stimuli based on the situation so that their perception is only partially affected when there is a change in the situation. His analytical nature will allow him to deal with what he receives by looking for the components that are embedded in the problems he faces.

This article has a research question in the form of: how is the numeration of FI students in solving social arithmetic problems at each cognitive level? It also aims to describe the numeracy of FI students in solving social arithmetic problems at each cognitive level. The purpose of this research is to broaden the researcher's understanding of student numeracy, with a particular focus on students who possess a FI cognitive style. Apart from that, this research looks at cognitive levels of numeracy, namely knowing, applying, and reasoning, which will add to the literacy material from previous research, which used aspects of mathematical literacy: formulate, employ, and interpret. Social arithmetic was chosen as material because it is one of the competencies expected to be achieved by students and is a frequent subject used in everyday life (Rahayu, Prahmana, & Istiandaru, 2021).

▪ METHOD

Participants

Participants in this research were students with a field-independent cognitive style. The selection of participants using purposive sampling was carried out after administering the Group Embedded Figure Test (GEFT) cognitive test to all class VIIF students at one of the state junior high schools in Surakarta. The GEFT test, which groups students based on their cognitive styles, is adapted from an instrument developed by Witkin. In this research, three participants were found to have a FI cognitive style, which henceforth will be symbolized as P1, P2, and P3.

Research Design and Procedures

Qualitative research was chosen as an alternative implementation with the research design used is a case study design. Qualitative research is an approach to exploring and understanding the meaning of a number of individuals or groups that originate from social or humanitarian problems and a case study design is a research design found in several fields, especially evaluation, in which researchers develop an in-depth analysis of a case, such as an event (Creswell, 2009). The case studied in this research is related to the numeracy of FI students at each cognitive level when solving social arithmetic problems. Table 1 shows the indicators of cognitive levels developed in this study.

Table 1. Indicators of cognitive level

Competency: Solving social arithmetic problems related to ratios/percentages	
Cognitive level	Indicator
Knowing	• Identify things that are known regarding ratios/percentages. (identify) • Explain the concept of ratio/percentage in solving social arithmetic problems. (explain)
Applying	• Creating mathematical models related to ratios/percentages to solve social arithmetic problems (creating models) • Apply the ratio/percentage concept to solve social arithmetic problems. (apply)
Reasoning	• Make conclusions based on ratio/percentage information when solving social arithmetic problems. (conclude) • Provide arguments to support claims regarding ratios/percentages in solving social arithmetic problems. (makes justification)

In order to assess the numeracy of FI students in solving social arithmetic problems, researchers conducted a test-based interview process to achieve data saturation, a sign of validity. Experts validated the test instruments and interview guides that researchers first developed. Once the researchers had determined the validity results of the auxiliary instruments, they proceeded to conduct research by administering social arithmetic test sheets to FI students, followed by interviews. This activity took place during two meetings between the researcher and the participants.

Research Instruments

Qualitative research is multi-paradigmatic with researchers working from different world views and making the field of inquiry very diverse, so researchers are involved in the research (Leavy, 2014). Thus, the researcher, as the main instrument acts completely to control the research process. This research also utilizes auxiliary tools, such as numeracy test instruments developed by researchers based on the development of Minimum Competency Assessment question types and interview guidelines. The auxiliary instrument is a test with two stimuli (Figure 1), each with three questions tailored to the cognitive level indicators in Table 1. The interview guide has been prepared as a reference for researchers to remain focused on what is being studied, however, the question items can be developed at the research location to obtain more in-depth information.

Several experts in their respective fields have validated both numeracy test instruments and interview guides. The research involved two mathematics education lecturers and a mathematics teacher at the school. The mathematics lecturer's validation process led to a significant revision of one question item and the addition of options to the answer, while the teacher's validation process involved adjusting the language to match the language level of class VII students.

Stimulus I

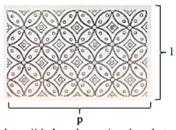
PAYDAY SALE

Platform layanan pesan antar makanan Shopeefood, selalu mengadakan "*Payday Sale*" setiap tanggal 25 dengan memberikan diskon makanan dan potongan ongkir. *Event* "Payday Sale" ini hanya berlaku untuk pembayaran menggunakan shopeepay. Tabel berikut menunjukkan daftar ketentuan penggunaan diskon, dan berlaku untuk semua toko makanan di Shopee.

Jenis diskon	Total diskon	Maksimal diskon	Minimal pembelian	Keterangan
Diskon Makanan	40%	Rp18.000,00	Rp30.000,00	
	50%	Rp15.000,00	Rp30.000,00	
Diskon Ongkir	50%	Rp5.000,00	Rp30.000,00	Berlaku di jam 11.00-12.00
	100%	Rp3.000,00	Rp30.000,00	Berlaku di jam 15.00-18.00
	100%	Rp1.000,00	Rp0	Berlaku dalam 24 jam

Stimulus II

BATIK PADA *FLY-OVER* PURWOSARI



(Sumber: https://sindunesia.com/gambar-sketsa-batik/)

Seorang seniman mural dipekerjakan pemerintah kota Solo untuk mempercantik jembatan *fly-over* di dekat Stasiun Purwosari dengan melukis beberapa ragam batik pada sisi kanan dan sisi kiri jembatan dalam berbagai ukuran. Sebelum memulai proses pelukisan, seniman telah membuat sketsa desain batik yang akan dilukis kembali ke dinding sisi kanan dan kiri jembatan pada selembar kertas. Salah satu sketsa desain batik pada kertas yang digunakan seniman dicontohkan pada gambar di atas dan ia telah membuat empat sketsa desain batik berbeda di kertas dengan ketentuan ukuran kertas terlampir pada tabel di bawah.

	Panjang (cm)	Lebar (cm)
Sketsa I	10	30
Sketsa II	15	20
Sketsa III	20	10
Sketsa IV	25	20

Figure 1. Stimulus used

Data Analysis

This research uses data analysis techniques according to the Miles, Huberman, & Saldaña (2014) model: (1) data condensation, (2) data display, and (3) conclusion drawing/verification. The process of selecting, focusing, simplifying, abstracting, and/or transforming data is known as data condensation. In this research, the data originates from the outcomes of numeracy tests and participant statements, which provide insight into their cognitive abilities. Test-based interview data condensation is classified based on the cognitive level indicators presented in Table 1 in general, namely identifying, explaining, modelling, applying, concluding, and providing arguments.

Presenting data entails classifying and identifying data, i.e., writing down an organized and categorized collection of data. The data presented in this research is carried out in the form of descriptive descriptions in the form of participant numeracy information in solving social arithmetic problems and remains based on cognitive level indicators (Table 1). The final stage is conclusion drawing/verification by providing meaning and explanation of the results of the data presentation.

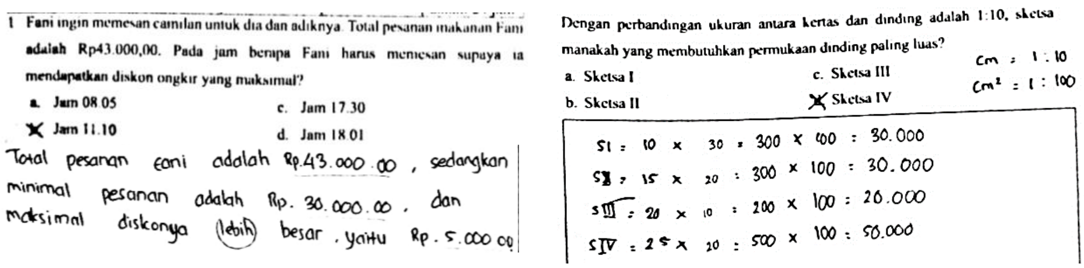
This study used time triangulation to examine the consistency of each participant's numerical solutions to social arithmetic problems. The researcher allocated the time for two meetings. The data obtained from each participant was then verified using source triangulation to see the consistency of the participants with a FI cognitive style. Consistent data remains based on the cognitive level indicators presented in Table 1. Data collection included observation, interviews, and document analysis.

▪ RESULT AND DISSCUSSION

The three participants answered all six social arithmetic problems developed by the researcher. The following provides an explanation and description of the numeracy of field-independent students in solving social arithmetic problems, as viewed from the perspective of the three cognitive levels (knowing, applying and reasoning). From now on, in the presentation of interview quotes, the researcher will be represented by the symbol R.

Cognitive level of knowing

The three participants found a solution to the knowing level problem, and all three answered correctly, as seen in Figure 2.


1 Fani ingin memesan camilan untuk dia dan adiknya. Total pesanan makanan Fani adalah Rp43.000,00. Pada jam berapa Fani harus memesan supaya ia mendapatkan diskon ongkir yang maksimal?
a. Jam 08.05
c. Jam 17.30
✗ Jam 11.10
d. Jam 18.01
Total pesanan Fani adalah Rp.43.000.00, sedangkan minimal pesanan adalah Rp. 30.000.00. dan maksimal diskonnya (lebih) besar. yaitu Rp. 5.000.00

Dengan perbandingan ukuran antara kertas dan dinding adalah 1:10, sketsa manakah yang membutuhkan permukaan dinding paling luas?
a. Sketsa I
c. Sketsa III
b. Sketsa II
✗ Sketsa IV
Cm : 1 : 10
Cm² : 1 : 100
SI : 10 x 30 : 300 x 100 : 30.000
SII : 15 x 20 : 300 x 100 : 30.000
SIII : 20 x 10 : 200 x 100 : 20.000
SIV : 25 x 20 : 500 x 100 : 50.000

Figure 2. P1's answer to the knowing-level problem

An excerpt from the researcher's interview with P1 regarding his answer to the first stimulus, explains that "*... generally 100% is more than 50%. However, let's take a closer look at the maximum discount. The 50% maximum is 5,000, while the 100% maximum is only 3,000 and 1,000. For instance, if you reduce the postage by 50% to a maximum of 5,000, it becomes 5,000; if you reduce it by 100% to a maximum of 3000, it remains 7,000."* Meanwhile, the quote from the researcher's interview with P1, regarding his response to the second stimulus,

"The question specifies a wall ratio of 1:10. Then, right, the measurements are in centimeters, so if square centimeters are squared, the result is 1:100," he continued with the statement, "... one sketch is 10 times 30 in size. So, if it is on the wall, the size will be 10 times larger than the sketch. This implies that the dimensions on the wall will be 100 times 300, sis."

Similarly, other participants responded to the researcher's inquiries in a manner largely akin to P1 of first stimulu. Followed by several confirmations from other participants when conducting the same interview, P2 explained that "... 5*0% means 50/100, 100% means 100/100. If it's 50%, that means you get a half price discount ...". This is in line with P3 who explained that "... at 50% and 100%, it becomes 50/100 and 100/100. If the discount is 40%, it means you will get a 40/100 discount from the original price, if it is 50% it means you will get a discount later half price."* Furthermore, for the second stimulus, P2 clarified that he comprehended the concept of 1:10 in the problem, meaning that if the paper's size was 1 the wall's size would be 10 times larger. And P3 explained that to find the size of the wall, you need to multiply 10 by the size in the sketch.

We conducted a test-based interview with P1, P2, and P3 to understand their responses to the numeration problem, both for the first stimulus and the second. We found that P1, P2, and P3 could recognize concepts related to ratios and percentages. This is consistent with Zhang (2004), who stated that FI is good at identifying objects; in fact, they tend to see objects or details as separate from their backgrounds. They can easily use ratios or percentages as a form of activity to identify information. It doesn't stop there; P1, P2, and P3 also demonstrate proficiency in the second indicator of the knowing level, which involves explaining the concepts of ratio and percentage. According to them, a percentage is dividing two numbers by one hundred, which, if you look closely, percentage is also a form of ratio. They easily represent the percentage form as a ratio concept, and this is in line with Gudladt (2023)'s research.

Cognitive Level of Applying

Each participant has found the right answer. Figure 4 shows the answers of two participants to the two stimuli given, and interview excerpts are also presented.

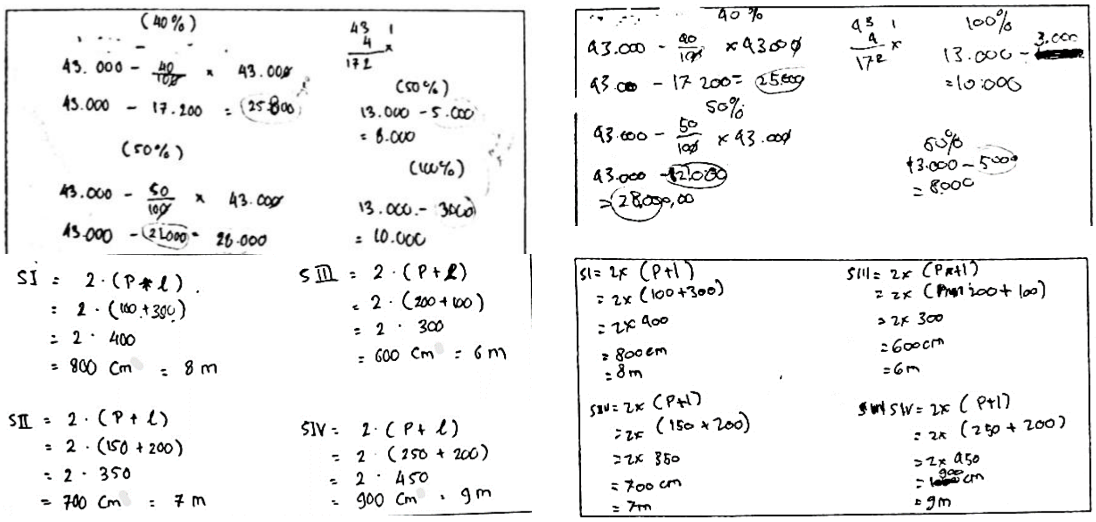


Figure 3. P1 and P2’s Answers to the applying level

The following is an excerpt from the researcher's interview with P1, and P2 and P3 were more or less the same in answering interview questions.

On the First Stimulus:

R : "Why is it specifically 13,000 minus 5,000 here, and 13,000 minus 3,000?”

P1 : "I already know, sis, that the maximum discount is 5,000 for 50% and 3,000 for 100%. So I just lowered it right away."

R : "But you know the plot, right?"

P1 : "It's like a food discount, right? Initial price minus discounted price. To calculate the discount price, I multiply 100% by 13,000 and 50% by 13,000. However, I reexamined the maximum discount that the table had previously established. Same as food discount, like I'm confused about how to write it because the original calculation used 21,000, but there's a maximum of 15,000, so I still wrote 21,000, even though the calculation used 15,000.”

In the Second Stimulus:

R : "Why do you use hundreds for length and width, even though the stimulus table uses tens?"

P1 : "Here, I directly use the units for the length and width of the wall, sis. I achieved this by applying a ratio of 1:10 to the problem.”

Based on the written test answers and the results of the interviews that have been conducted, it is known that P1, P2, and P3 created a mathematical model related to percentages (in this case, price discounts) by multiplying the percentage in the form of a ratio with a denominator of 100 by the initial price. Each participant applies this model to achieve their desired results. Even though it appeared that the participants were wrong in their writing, they actually wrote the right things. The stimulus table, which presented the maximum number of pieces, guided the three participants, demonstrating their double-checking process for detailed information (Zhang, 2004). The process of double-checking aligns with metacognitive monitoring, as it involves assessing the accuracy of one's own judgments or decisions (Chew, Van Merrienboer, & Durning, 2019; McMullan, Urwin, Wiggins, & Westbrook, 2023).

In terms of the ratio in the second stimulus, both P1, P2, and P3 implicitly created mathematical models in their thinking. Although they did not explicitly state that they obtained the length and width from a ratio of 1:10 in the problem, they were aware that the size on the wall was 10 times larger than the sketch. It can be said that all participants have applied a scale of measurement, which is defined as the comparison between the units of measurement in the sketch and the actual size (Ben-Chaim, Keret, Ilany, & Hany, 2012), with the number of times the size of the object can be enlarged or reduced (Menduni-Bortoloti & Barbosa, 2017). However, the participants applied an appropriate mathematical model to solve the problem. Participants also converted centimeters into meters, which indirectly applies the ratio concept (Vysotskaya, Lobanova, Rekhtman, & Yanishevskaya, 2021). Yanishevskaya (2023) suggests using this as a proportionality-based concept teaching strategy to indirectly apply the concept of ratio.

Cognitive Level of Reasoning

The three participants have solved the last arithmetic problem, which is related to the cognitive level of reasoning. When the participants were interviewed in more depth, the answers between the three were similar, so the interview excerpt that will be described is only representative of one of the three participants.

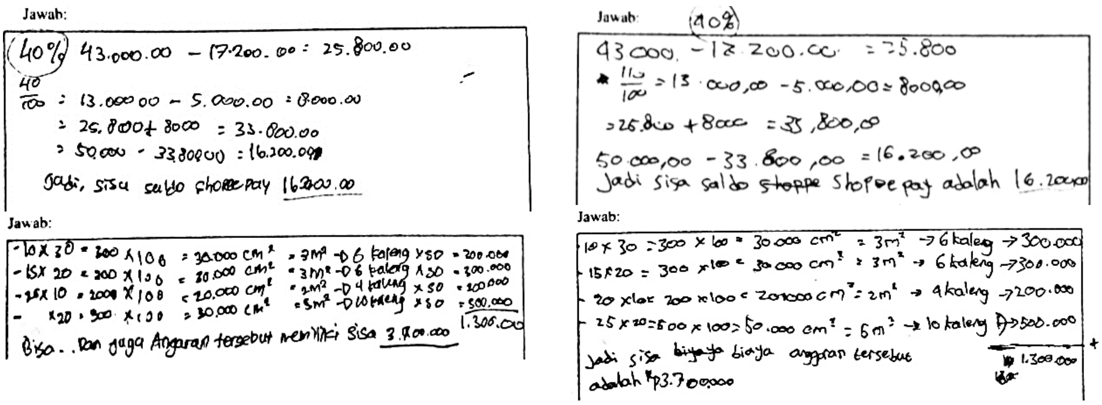


Figure 4. P2 and P3’s answers to the reasoning level

According to Figure 4, both P2 and P3 begin their work by subtracting the initial price and discounts (both on food and postage) to determine the costs used. Below is another excerpt from the researcher's interview with P3 about the first stimulus.

R : "Why is your answer directly 43,000 minus 17,200 and 13,000 minus 5,000?"

P3 : "We calculated a starting price of 17,200 by subtracting 40% from 43,000. This means 40/100 times 43,000. I chose 40% because the maximum discount is 18,000 which is clearly bigger than 50%, which is only 15,000. 5,000 because the maximum postage discount is that much, if there is no maximum, then the shipping cost will be 6,500, from 13,000 minus 50%."

In the second stimulus:

R : "Can you explain where you got your writing that 'has 3,700,000 remaining'?"

P3 : "Start by identifying the area, then count the number of cans, multiply it by the paint price, and finally add up the total." For example, in the first row, 300 represents the area in the sketch. In this case, the ratio is 1:10 for centimeters, which translates to a ratio of 1:100 for square centimeters. Therefore, you need two cans of paint per square meter, which means that if you have 3 square meters, you will need 3 times 2 cans of paint, which equals 6 cans."

Based on the results of written answers P2 and P3, it is known that participants can draw a conclusion that answers the question about the problem that has been presented. The conclusion drawn is also similar to P1's conclusion. Apart from that, participants can also conclude that a 40% gratuity with a maximum discount of IDR18,000 will provide a bigger discount than a 50% gratuity with a maximum discount of IDR15,000, so they choose to use 40%. This shows that participants are careful in selecting the information used so that it has an effect on their reasoning (Brase, Osborne, & Brandner, 2019). In both the first and second stimuli, all participants did not use rupiah notation for the conclusions they reached. Although mathematics uses notation to represent meaning, it is critical in communication because it concisely and clearly expresses ideas (Edwards & Auger-Méthé, 2019; Gnoli, 2018).

The described test-based interviews reveal that P3, along with the other two participants, can provide arguments that substantiate claims about ratios and percentages. They are capable of determining the most advantageous discount percentage to apply. This provides information that enables participants to understand a problem's ultimate goal and apply relevant rules as a key to solving it (Helmold, 2021). In addressing these two problems, the three participants employed procedures that incorporated information on ratios, percentages, and other general concepts. Showing that they can exploit what is already known packaged with adaptable knowledge to arrive at conclusions (Johnson-Laird, 2010).

▪ CONCLUSION

This research focuses on field-independent students' numeracy, specifically examining their cognitive level—knowing, applying, and reasoning—in solving social arithmetic problems related to ratios and percentages. At the cognitive level of knowing, FI students are able to meet both of the existing indicators. They are capable of identifying familiar concepts related to ratios and percentages, and they can articulate these concepts to solve social arithmetic problems. At the cognitive level of applying, FI students can create mathematical models relating to ratios and percentages and apply them to solve social arithmetic problems. When solving social arithmetic problems, FI students can draw conclusions based on ratio and percentage information and provide arguments to support those claims at the cognitive reasoning level.

The existence of two distinct cognitive styles, FI and field-dependent, is indisputable. However, this study's limitation stemmed from the fact that it only included participants with the FI cognitive style. Apart from that, there is a lot of mathematics content that can be another consideration for looking at students' numeracy skills, and the selection of social arithmetic content is a second limitation of this research. Therefore, exploration of numeracy skills in other mathematical content can produce new insights based on indicators formed as derivatives from other mathematical content.

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