



## Students' scientific reasoning on temperature and heat topic: A comparative study of students in urban and rural area

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**Abstract:** This study aims to describe the scientific reasoning level of students in urban and rural areas on heat and temperature topic. This current study involved 104 students from two schools in urban areas and three schools in rural areas. The instrument used was a six-item essay test. The result showed that the students' scientific reasoning score was still low. However, based on the Mann–Whitney test, the study found that there was a significant difference in scientific reasoning scores between students in urban and rural areas. Both students in urban and rural areas were indicated to have higher proportional reasoning when compared to the other kinds of scientific reasoning. In particular, students' proportional reasoning in urban areas was higher than in rural areas. The result also showed that probabilistic reasoning and correlational reasoning of students in the rural area tended to be unstable compared to students in the urban area. The implication is that physics teachers in the rural area should make maximum use of the facilities in practicing student reasoning skills.

**Keywords:** rural area; scientific reasoning; temperature and heat; urban area

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### Introduction

Educational equality receives tremendous attention across the world. It was not only a discourse topic in developing countries (Champahom et al., 2019) but also in developed countries (Crawley et al., 2019). The gaps between student conditions in urban and rural areas reported in many studies (Vitale et al., 2019; Zarifa et al., 2019). Most of the reports showed that the gaps happen in technology use (Loong et al., 2011; Wu et al., 2019). Mudra (2018) study informed about some obstacles when teaching in a rural school in Indonesia. The study mentioned that learning materials or resources, learning media, slow internet connectivity, choice of language use, learners' motivation, and parental support were the barriers in Indonesian rural school.

The previous study used a varied indicator to analyze the gap between urban and rural schools. For example, Zhang et al. (2015) generally used an academic performance term to show the difference between the educational system in urban and rural schools in China. On the other hand, Keys (2015) analyzed the difference between family engagement for urban and rural students. Wu et al. (2019) investigated the urban and rural gap by analyzing ICT support. There are so many ways to analyze the shift between urban and rural school systems.

In particular, science education used a nuance indicator to measure student competence. For example, using scientific reasoning to capture the students' skills. Across the world, science education research has more concern about scientific reasoning (National Research Council (U.S.), 2012).



Scientific reasoning could help students in making decisions about the problems faced (Engelmann et al., 2016). Scientific reasoning includes generating, testing, and revising hypotheses/theory (Morris et al., 2012). In practice, scientific reasoning can also be used as a formative assessment to help students reflect on what they have taught (Ibrahim et al., 2016). In addition, scientific reasoning can actually help students understand specific knowledge including physics (Andersen & Garcia-Mila, 2017). However, most scientific reasoning so far has been measured in the general context (Rimadani et al., 2017). Very few studies have examined scientific reasoning on specific topics.

Scientific reasoning on temperature and heat topic is an example of scientific reasoning in a specific domain. Rimadani et al. (2017) found that students' scientific reasoning on the temperature and heat topic was still relatively low. The temperature and heat topic is easily found in everyday life (Fernandez, 2017). Therefore, students must be able to reason if they want to give an explanation related to the temperature and heat phenomenon correctly. This is an important skill for students after studying at the school level (National Research Council (U.S.), 2012).

Scientific reasoning in specific contexts is important for all students from various backgrounds to have. Despite there are no consensus about the correlation between scientific reasoning and other aspects related to the students (Ding et al., 2016), students' academic background still has a potential to effect the students' scientific reasoning. The experience of students in different urban and rural environments. For students in the urban area, access to information is easier to obtain than students in the rural area. This will make students' initial understanding related to scientific concepts tend to be different because students' explanations of a phenomenon are influenced by students' daily lives and interactions with their environment (Hitt & Townsend, 2015). Studies are still rarely found that discusses the characteristics of scientific reasoning patterns from the point of view of the students' characteristics in the urban and the rural area.

Based on the above explanations, integrative investigations related to the gap between urban and rural student competence could be done by analyzing the student scientific reasoning. This research is expected to be able to complete and fill the void of research studies in the field of scientific reasoning, especially in the context of developing countries such as Indonesia.

### **Method**

This current study was a survey study to provide an overview of students' scientific reasoning patterns in urban and rural areas. There were three patterns of scientific reasoning identified in this study, namely: probabilistic reasoning, proportional reasoning, and correlational reasoning. The study involved five high schools, two schools in East Java (one from Malang City and one from Blitar City) and three schools in South Sulawesi (one from Gowa Regency, one from Pangkajene and Kepulauan Regency, and one from Sidrap Regency). Two schools originating from East Java were referred to be the urban area schools and three schools originating from South Sulawesi were referred to be the rural area schools. For information, the three schools in South Sulawesi are not located in the regency capital. Based on observations, the categorization of students in urban and rural was not only based on regional differences but also based on access to learning where students in the urban area were having easier access to learning compared to students in the rural area. The facilities at city schools were more complete than those at rural schools. In addition, students from urban schools are born to educated parents compared to students from rural schools. Data related to how education disparities still occur in Indonesia can be seen in (Badan Pusat Statistik, 2019).

Purposive sampling was used as a technique in attracting research subjects. A total of 104 subjects were included. In detail, the distribution of research subjects can be seen in Table 1.

Scientific reasoning on the heat and temperature topic was measured by the six-item essay test. Questions number 1 and 2 were designed to measure the probabilistic reasoning patterns. Question number 3 and 4 were related to proportional reasoning patterns. Question number 5 and 6 were related to the pattern of correlational reasoning. The instrument was validated by an expert and implemented on 40 high school students as an empirical test. The correlation coefficient between items with total scores varied from 0.523 ( $p < 0.01$ ) to 0.712 ( $p < 0.01$ ). Difficulty level from

0.26 (moderate) to 0.57 (difficult). The alpha Cronbach coefficient of this instrument is 0.626. Those results indicated that the instrument has appropriate to use. In detail, the construction of the instrument present in Table 2.

**Table 1.** Participants Distribution

Participant	School	Number of participants	Total
The student in the urban area	A	18	49
	B	31	
The student in the rural area	X	24	55
	Y	11	
	Z	22	
Total of participant			104

**Table 2.** Description of The Instrument

Item Number	Scientific Reasoning Pattern	Indicator of The Item
1.	Probabilistic reasoning	Analyzing the results of an experiment about the temperature measurement of a substance probabilistically
2.	Probabilistic reasoning	Analyzing the result of an experiment about the relationship between heat and temperature changes
3.	Proportional reasoning	Applying the concept of heat capacity
4.	Proportional reasoning	Analyzing the equality between electrical energy and heat
5.	Correlational reasoning	Correlating the relationship between heat and increase in temperature, mass of substance, specific heat capacity, or heat capacity
6.	Correlational reasoning	Correlating the relationship between material characteristics and heat transfer

**Table 3.** The Scientific Reasoning Pattern Category

Scientific reasoning	Level	Category	Description
probabilistic reasoning	0	No answer	Does not provide answers/explanations/reasons
	1	Intuitive (I)	Guess answers, use numbers or settlement strategies randomly (carelessly) and answers are not logical
	2	Approximate (Ap)	Provide an explanation/reason with a qualitative description
	3	Quantitative (Q)	Provide explanations/reasons with quantitative descriptions
proportional reasoning	0	No answer	Does not provide answers/explanations/reasons
	1	Intuitive (I)	Guess answers, use numbers or settlement strategies randomly (carelessly) and answers are not logical
	2	Adaptive (A)	Use a settlement strategy but focus on different things
	3	Transitional (Tr)	Implement and use an equation strategy with a ratio and determine the value but it is not right
correlational reasoning	4	Ration (R)	Apply and use an equation strategy with ratios and determine values precisely
	0	No answer	Does not provide answers/explanations/reasons
	1	Intuitive (I)	Guess answers, use numbers or settlement strategies randomly (carelessly) and answers are not logical
	2	No Relational (NR)	Give reasons/explanations but between the things described are not interrelated
	3	One Cell (OC)	Give reasons by explaining the relevance to one problem
4	Two Cell (TC)	Give reasons by explaining the linkages to the two problems	
5	Correlational (Co)	Provide reasons and explanations precisely for all problems by explaining the relationship between the problem and reason	

Data were analyzed with inferential and descriptive statistics. For comparative analysis, the Man-Whitney test was used to find the difference between students' scientific reasoning in urban and rural areas. Student answers were grouped according to the level of reasoning patterns. Student

answers were analyzed using rubrics adapted from Karplus et al. (1980). Data at all levels were then presented in diagrams form. The description of each level of scientific reasoning present in Table 3.

## Results and Discussion

### Results

Comparative analysis was done by using the Mann–Whitney test. We could report that the scientific reasoning score of students in urban areas was significantly different from students in rural areas,  $U = 654.00$ ,  $p < .001$ . In particular, the comparison of students' scientific reasoning in urban and rural areas is shown in Table 4.

**Table 4.** The Means Score of The Students' Scientific Reasoning in Urban and Rural Areas

	Mean Score	
	Students in urban areas	Students in rural areas
Scientific reasoning	45.60 (SD=15.37)	31.67 (SD=15.37)
Probabilistic Reasoning	42.52 (SD=19.86)	26.53 (SD=20.67)
Proportional Reasoning	60.71 (SD=33.56)	35.71 (SD=33.07)
Correlational Reasoning	37.76 (SD=16.36)	31.63 (SD=20.34)

Table 4 shows that the total of students' scientific reasoning score in urban areas ( $M=45.60$ ,  $SD=15.37$ ) is higher than the students in rural areas ( $M=31.67$ ,  $SD=15.37$ ). Proportional reasoning is the highest reasoning pattern for both students in urban and rural areas (60,71 and 35.71 respectively). For the lowest score, students in urban areas are different between students in urban and rural areas. Correlational reasoning is also the lowest score for students in urban areas (37.76). On the other hand, students in rural areas faced probabilistic reasoning as the lowest scientific reasoning score.

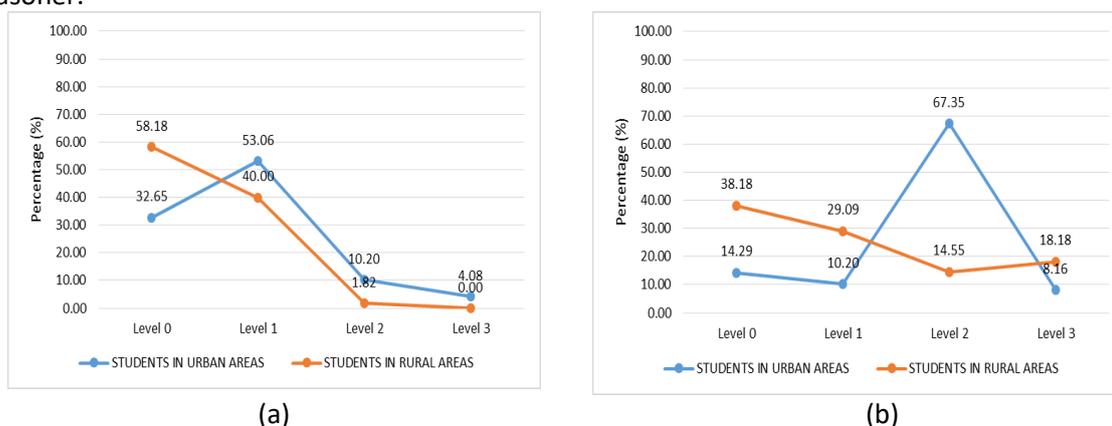
In accordance with the objectives of this study, the researcher analyzed the students' scientific reasoning in urban and rural areas based on three types of scientific reasoning (i.e. probabilistic reasoning, proportional reasoning, and correlational reasoning). The first, probabilistic reasoning was analyzed from two different contexts. The first question is related to the temperature measurement experiment and the second problem is about heat and temperature experiments. The first problem is as follows.

Ali takes two glass bottles filled with water at  $20^{\circ}\text{C}$  and wraps them in a cloth. One bottle is wrapped in a wet cloth while the other is in a dry cloth. 20 minutes later, he measured the temperature of the water in each bottle. Water in bottles wrapped in wet cloth is  $18^{\circ}\text{C}$ , while water in bottles wrapped in dry cloth is  $22^{\circ}\text{C}$ . (cloth conductivity =  $0.040 \text{ J / m.s.C}^{\circ}$ , water conductivity =  $0.56 \text{ J / m.s.C}^{\circ}$ )

- What was the most likely room temperature during the experiment?
- Explain your answer!

Two questions are used to measure students' probabilistic reasoning in urban and rural areas. Figure 1 presents the percentage of students' probabilistic reasoning. Figure 1 illustrates the difference in the percentage distribution of probabilistic reasoning patterns of students in urban and rural areas. In Figure 1 (a), the percentage of students who categorized as level 0 (i.e. do not provide an answer) is relatively high. It is about 32.65% for students in urban areas and 58.18 for students in rural areas. Similar to level 0, level 1 (intuitive) is also high relatively; it is about 53.06% for students in the urban area and 40.00% for students in the rural area. The crucial finding was found that none of the students in the rural areas have the highest level of probabilistic reasoning pattern; it is level 3.

It could be concluded that there were no students from rural areas categorized as quantitative reasoner.



**Figure 1.** Levels of Students' Probabilistic Reasoning: (a) The Temperature Measurement Experiment Problem; (b) The Heat and Temperature Experiment Problem

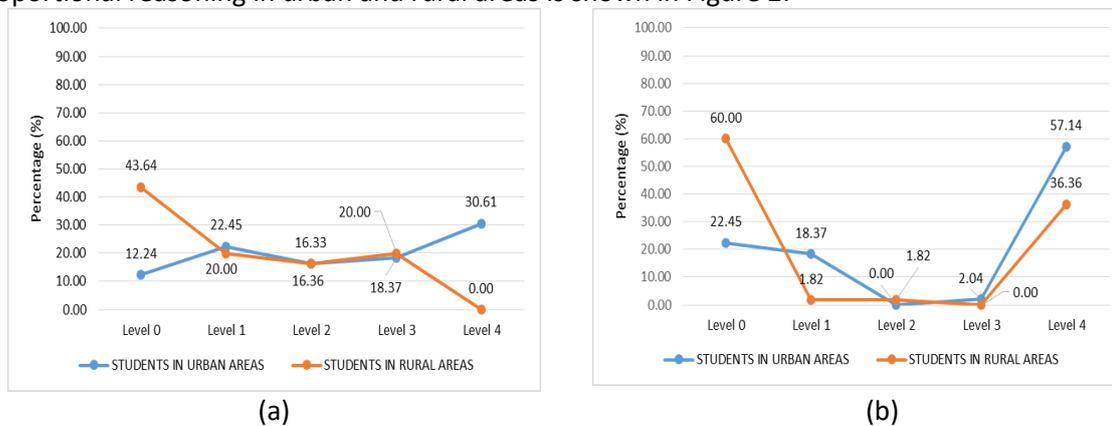
In Figure 1 (b), there was a difference between students in the urban and rural areas who categorized as level 2 (approximate) of probabilistic reasoning. It shows that 67.35% of students in the urban area categorized as level 2 while in students in the rural area only 14.55%. Furthermore, the percentage of students who categorized as level 3 (quantitative reasoner) of probabilistic reasoning in urban and rural areas is 18.18% and 8.16% respectively.

Other results showed that the patterns of probabilistic reasoning of students in rural area tend to be inconsistent. In the problem of a temperature measurement experiment, none of the students were at level 3. Meanwhile, in heat and temperature experiment problem, it is about 18.18% of students who categorized as quantitative reasoners (level 3). It is expressively higher than students in the urban areas which is only 8.16%.

The second reasoning pattern measured in this study was proportional reasoning. One example of a question item about proportional reasoning is as follows:

Object X and object Y are two different metals. If object X requires 1,500 J heat so the temperature rises from 40°C to 50°C. What is the heat required to increase the temperature of object Y from 20°C to 25°C if the heat capacity of object X is twice the heat capacity of object Y?

There were two questions to measure students' proportional reasoning. The question above measures students' proportional reasoning on heat capacity problems. Another question is about the proportional reasoning in heat and electrical energy problems. The percentage of students' proportional reasoning in urban and rural areas is shown in Figure 2.



**Figure 2.** Levels of Students' Proportional Reasoning: (a) The Heat Capacity Problem; (b) The Equality between Electrical Energy and Heat Problem

Figure 2 shows the difference in the proportional reasoning of students in urban and rural areas. Figure 2 (a) shows a quite extreme difference in level 4 (ration). It is about 30.61% of students in the urban area who are in the level 4 category. In contrast, there are no students in the rural areas who are at level 4. Also, the percentage of students in rural areas who do not give answers to question number 3 is quite high which is about 43.64%.

Figure 2 (b) shows that both students in the urban and rural areas have a good proportional reasoning pattern that is 51.14% and 36.36% respectively categorized at level 4 (ration). However, as with question number 3, the percentage of students who do not give answers is still slightly high (about 22.45% and 60.00% respectively).

In particular, the distribution of student answers in the urban areas both in heat capacity problems and electrical energy and heat problem is still relatively similar in their level of scientific reasoning. In contrast, the rural area students who categorized as ration reasoners (level 4) in electrical energy and heat problem were about 36.36% while in heat capacity problem there are not any students in level 4.

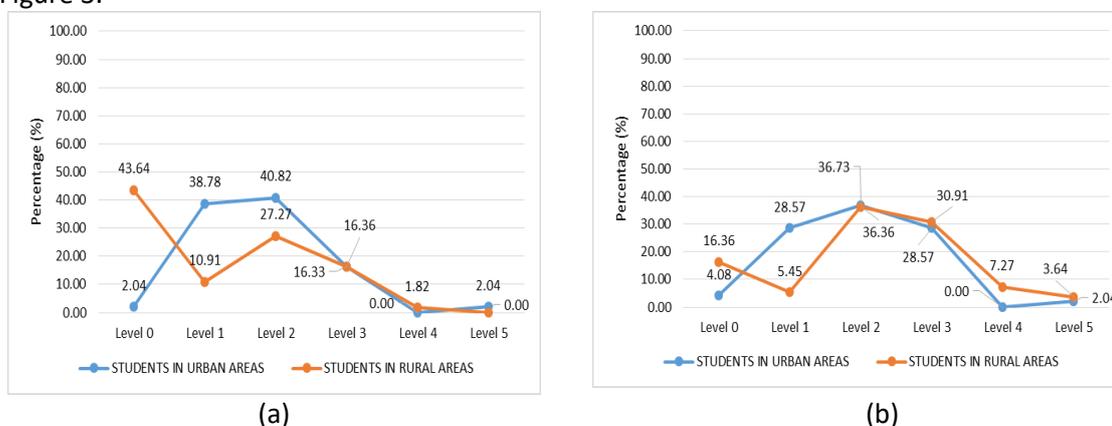
The third pattern of scientific reasoning investigated in the present study is correlational reasoning. One question aimed to measure students' skills to correlate some variables related to heat and temperature concepts. The question related to the correlational reasoning problem is presented as follows.

100 grams of ice at 0°C and 100 grams of water at 0°C are put in the freezer to -4°C.

- a. Which of the two will lose the biggest heat?
- b. Give some reasons why you answer that way!

Adapted from (Yeo & Zadnik, 2001)

There are also two questions to measure students' correlational reasoning. One question is presented above and the other question is about the correlation between heat transfer concept and material characteristics. The percentage of students at five correlational reasoning levels is presented in Figure 3.



**Figure 3.** Levels of Students' Correlational Reasoning: (A) The Relationship between Heat and Increase in Temperature, Mass of Substance, Specific Heat Capacity, or Heat Capacity; (B) The Relationship Between Material Characteristics and Heat Transfer

Figure 3 illustrates the distribution of correlational reasoning between students in urban and rural areas. In Figure 3 (a), there are about 43.64% of students who did not give answers and it was very different from students in the urban that only 2.04% of students who did not give answers. There are about 2.04% of students who are at level 5 (correlational) while in the rural area no one students are at level 5.

In Figure 3 (b), level 2 (no relational) is the highest level of scientific reasoning for both students in urban and students in rural areas (36.73% and 36.36% respectively). In addition, in the highest level of correlational reasoning, Figure 3 (b) also shows that students in the rural areas at level 5 are higher than students in the urban areas with percentages of 3.64% and 2.04% respectively.

## Discussion

There were some results of this study. The statistical analysis showed that there was a significant difference in scientific reasoning scores between students in urban and rural areas. The scientific reasoning of students in urban areas was statistically different among students in rural areas. By analyzing three dimensions of scientific reasoning, proportional reasoning was the highest scientific reasoning for both students in urban and rural areas. There were different lowest scientific reasoning of students in urban and rural areas. Furthermore, all of the scientific reasoning patterns could be grouped at the appropriate level.

In particular, proportional reasoning was a pattern of scientific reasoning with a relatively high percentage both in urban and rural students. Furthermore, the results of the analysis showed that proportional reasoning in urban areas is higher than students in rural areas. Another result of this study is that students in rural areas tend to be inconsistent in using probabilistic reasoning and correlational reasoning patterns. For example, in probabilistic reasoning, students dominantly categorized as quantitative reasoners (Level 3) in heat experiment problem than temperature measurement experiment problem. It implied that students more success to analyze the relationship between heat and temperature changes than determine the temperature of a substance and environment probabilistically.

The proportional reasoning pattern of students is the best reasoning pattern between the two other scientific reasoning patterns. This is in line with the results of Ding (2018) study that high school students showed an earlier increase in proportional reasoning patterns compared to other patterns of reasoning. Erlina et al. (2018) also found that despite being given treatment, the ability of students in correlational reasoning was still in the lower category and proportional reasoning was slightly higher in the medium category. However, some things also need to be noted that this type of proportional reasoning problem is more mathematical when compared to correlational and probabilistic reasoning problems. Beginner students tend to start solving problems by modifying mathematical equations but do not understand concepts (Kuo et al., 2013). This allows students to be able to apply physical equations in various phenomena but sometimes have difficulty to analyze why the phenomena occur. Students have difficulty to solve some conceptual problems completely (Woolley et al., 2018).

Students' probabilistic and correlational reasoning in urban and rural areas is still low. Probabilistic reasoning is represented by the first and the second question indicator (see Table 2). The first indicator is about analyzing the temperature measurement experiment of a substance probabilistically. Many students from urban and rural areas did not provide an answer to this problem. It made the mean score of students probabilistic reasoning tended to low. The result of this study echoes those past research relatively to Morris et al. (2012), and Zimmerman (2000) that scientific reasoning cannot be separated from a specific domain or scientific concepts. The second indicator related to analyzing the experiment about the relationship between heat and temperature changes. Students more success to answer the second question than the first question. It may cause students to need to elaborate on the process of cooling and heating by considering the heat flow in the first problem. Heat flows from the higher temperature spot to the lower temperature spot (Chu et al., 2012). On the other hand, students only need to make a connection between heat and temperature in the second problem. According to Leighton & Sternberg (2013), the reasoning could be connected to problem-solving. Indeed, students' conceptual understanding has a significant role in the students' reasoning process.

Moreover, correlational reasoning was measured by using two indicators which is the fifth and the sixth question indicator. The fifth question indicator is correlating heat, temperature, mass of substance, specific heat capacity, and heat capacity. The sixth indicator is about correlating material characteristics and heat transfer. In the fifth and the sixth problem, most of the students did not consider all variables when they solve the problems. This result may be caused by the characteristics of the problem. Basically, proportional reasoning is indeed more widely used in mathematics (Brown et al., 2019; Dubovi et al., 2018; Hilton et al., 2016). On the other hand, correlational reasoning needs

more elaboration about scientific evidence. This part highlight by Fischer et al. (2014), they believed that scientific reasoning is very closed with scientific argumentation. Besides, this study also confirmed students in the rural area tend to be inconsistent in the pattern of probabilistic reasoning and correlational reasoning compared to students in the urban area. The inconsistencies in both of these reasons are usually caused by students not considering all the causal factors and are very dependent on prior knowledge (Woolley et al., 2018). For example, several students did not involve the role of latent heat when the water form changed from liquid to solid state. This result also found by Maunah and Wasis (2014).

The proportional reasoning pattern of students in urban areas is higher than that of students in rural areas. The third and fourth question indicators described as students' proportional reasoning. The third and fourth indicator is applying the concept of heat capacity and analyzing the equality between electrical energy and heat respectively. Both the third and fourth indicators indicated that students in urban areas performed better than students in rural areas. This can be caused by differences in educational characteristics in both urban and rural areas. One of the striking differences between schools in rural and in urban in Indonesia is the existence of a science club (OECD, 2016). Schools in the urban area more facilitate students with science groups that can help students learn science. The results of Gottfried & Williams (2013) research showed that there are differences in learning outcomes between students who take and those who do not join the science extracurricular groups. Through such activities, student reasoning can develop. Another possible cause is the socioeconomic effect. The results of Takashiro (2017) study showed that the socioeconomic differences of parents' students have a significant relationship with student learning outcomes. In addition, a study conducted in Russia by Amini and Nivorozhkin (2015) stated that the main factor influencing student performance is not school facilities but students' socioeconomic factors. Therefore, this result becomes an indication for the next research by exploring the consistency and factors that influence the students' scientific reasoning in urban and rural areas.

### **Conclusion**

Based on the results of the analysis and discussion in the previous section, it can be concluded that there was a significant difference in scientific reasoning scores between students in urban and rural areas. Particularly, students' proportional reasoning in urban and rural areas was better than the other two patterns of reasoning. These results also indicate that students tend to be better able to solve mathematical problems than conceptual ones. In the probabilistic pattern of reasoning and correlational reasoning, the reasoning of students in urban is more consistent than students in rural areas.

This research implies that scientific reasoning training needs to pay attention to students' characteristics. One way that can be done is to teach explicit ways of reasoning to students with low abilities should (Nieminen et al., 2012). In other words, if the average ability of students in rural areas is lower than the scientific reasoning training for students in rural areas must be more explicit compared to students in urban students. In general, this can be a solution not only for students in rural areas but also for students in urban areas. Finally, differences in facilities and socio-economic students in cities and villages can be overcome by appropriate reasoning training. Another implication that is no less important is to train students in reasoning that is conceptual and not only mathematical in both students in the urban and in the rural areas. This can be done by utilizing learning resources available around the school

The results of this study can be used as a basis for determining the way of scientific reasoning training to students. The three patterns of scientific reasoning discussed in this article can be practiced by considering students' learning abilities and access. Not just looking at location differences, scientific reasoning training needs to consider various aspects. Further research can be done by observing the consistency and factors that influence students' scientific reasoning in urban and rural areas. Besides, studies can also be developed on different topics and with a more varied type of student demographic

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