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Does demographic background matter on students' mathematical problem-solving based-integrated STEM?

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ABSTRACT: The trend of interdisciplinary mathematics that integrates STEM answers the challenge of 21st-century skills but raises issues of student difficulty and achievement gaps among students. The predicted reasons are the result of the demographic background. School location and age are the debatable demographic backgrounds that created the difference in students' mathematics problem-solving skills. The present study examines the significant differences in student mathematical problem-solving skill-based integrated STEM based on gender and school location. It was conducted on 116 7th-grade students from rural and urban areas in Indonesia (M = 13.09, SD = 0.61). The problem-solving skills were assessed using an essay scenario-based test followed by a demographic background questionnaire. The data was analyzed by using an independent sample t-test. Results revealed no significant difference in students' mathematical problem-solving skills based on integrated STEM based on gender in rural and urban schools. In addition, there were significant differences between students who attend urban and rural schools in their mathematical problem-solving skills-based integrated STEM and urban outperforming those from rural schools. The difference was detected in female participants. Further study suggests enlarging the sample size and involving more varied participants.

1 INTRODUCTION

Mathematics is fundamental to learning other subjects and survival knowledge in daily life (Junpeng et al. 2020; Kesorn et al. 2020). From elementary to high school, mathematics became a required subject. The impact of global economic transformation transforms the trend of monodisciplinary mathematics into interdisciplinary mathematics by incorporating STEM (Kelley & Knowles 2016; Maass et al. 2019).

Shifting mathematics into an interdisciplinary-based is raising issues regarding students' difficulties and achievement gaps. Students encounter difficulty in mono-disciplinary and interdisciplinary mathematics problems, including understanding a problem, translating the problem into mathematical words, and using mathematics concepts (Phonapichat et al. 2014; Siniguian 2017; Tambychik & Meerah 2010). Several affective, cognitive, and demographic factors could affect these issues.

Studies examining the factors influencing differences in students' problem-solving skill-based integrated STEM were rarely found (Bartholomew & Strimel 2018), primarily related to the demographic background (Nepal 2017). Researchers tend to focus on cognitive and affective reasons rather than demographic reasons; indeed, it could be an essential contribution to predicting students' gaps in mathematics problem-solving achievement

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(Nepal 2017). Demographic refers to district characteristics of a population, e.g., race, age, sex, Etc. The controversial demographic background that is responsible for problem-solving skills differences is gender, and school type since the results of previous studies was not inconsistent and are still debatable (Lee & McIntire 2000; Li et al. 2018; Lindberg et al. 2010; Ramos et al. 2021; Williams 2005).

The location of school segregation is often accompanied by school segregation (Tomul et al. 2021). If the school's location is in a rural area, it will affect the quality of the school (Ramos et al. 2021). The socio-cultural and socio-economic characteristics of a residential area where the school is located influence academic achievement (Tomul et al. 2021). Hence, it is crucial to examine the school location as a factor that might create the differences in students' mathematics problem-solving skills based on integrated STEM.

The most debatable factor influencing mathematics skills is gender (Zhu 2007). Gender differences in mathematics performance have received much attention in the psychological, educational, and sociological fields (Li et al. 2018). Research about gender differences in mathematics was found in the 1970s (Leder 2019). However, in the 21st century, many results were discovered. Some argue that STEM is stereotyped as a male domain based on a biological perspective, and some argue that gender equality in mathematics is based on a sociological perspective (Catsambis 2005; Davies & Spencer 2005; Halpern et al. 2005; Lindberg et al. 2010). Therefore, it is interesting to contribute by examining whether there is a gender difference in solving mathematics problems based on integrated STEM to prove which theory is applicable nowadays.

According to the aforementioned critical reasons, the present study aims to examine the significant difference in students' mathematics problem-solving skills integrated STEM based on gender and school location. The results will be helpful as a fundamental theory to improve students' mathematical problem-solving skills, to understand the source of inequality (if any), and to improve our understanding of how students learn.

2 THEORETICAL BACKGROUND

The variable predicting achievement is the characteristic of the school locations within the country (Ramos et al. 2021; Tom et al. 2021). Students who attend rural schools have a worse educational outcome in mathematics, science, and reading than students who attend an urban school in Columbia (Ramos et al. 2021). Another research across countries using PISA 2009 data concluded that students in rural schools had significantly low mathematics scores in 14 of 24 countries (Williams 2005). In addition, research in Nepal examined the effect of gender and school location on mathematics thinking (including problem-solving) and mathematics achievement (Nepal 2017). The results revealed there were significant differences between urban and rural students in mathematics thinking skills ($t = -5.11$, $p < .001$) and mathematics achievement ($t = -4.45$, $p < .001$).

There were different patterns and variations in the finding of mathematics achievement in other countries, with rural school students outperforming urban schools (Lee & McIntire 2000; Williams 2005). Several factors could predict these variations, namely lack of instructional resources (e.g., facilities, materials, programs, Etc.), lack of professional training (e., teacher training), and lack of progressive instructions (Lee & McIntire 2000).

2.1 *Gender and mathematics skills*

Research about gender differences in mathematics was begun in the 1970s with the work of Fennema and her colleagues (Leder 2019). They stated gender differences in the upper elementary and early high school, with boys favoring higher-level cognitive tasks in mathematics. In the 1980s, the programs of gender equality in mathematics education were raised until, in 1990, Hyde et al. did a meta-analysis that reviewed 100 studies between 1963 and

1988. Results revealed (1) gender differences in mathematics performances were negligible ($d=-0.05$) and favored females; (2) girls did slightly better than boys in computation, and there were no gender differences in problem-solving for elementary and middle school levels, but males outperformed in college-level; (3) the effect size of gender differences declined over the years. In the 2000s, the meta-analysis study by Lindberg et al. (Lindberg et al. 2010) proposed strong evidence of gender similarity in mathematics performance. They used 242 studies from 1990 to 2007 and represented the data of 1,286,350 people. The results concluded (1) the gender difference weighted overall studies were small ($d = 0.05$); (2) few statistically significant differences in performance; (3) slight gender differences in complex problem-solving were found in high school with boys outperforming girls; (4) the effect size of gender differences decreased over time. Another meta-analysis study using data in Beijing stated that there were no gender differences in mathematical achievement among grade 5 students; relatively small differences exist in grade 8 (Li et al. 2018).

The reviews' results related to gender similarity in mathematics were supported by several studies (Ajai & Imoko 2015; Nepal 2017). Nepal (2017) concluded that there were no gender differences in mathematics thinking skills ($t=-454$, $p = .65$), problem-solving ($t=-.480$, $p = .632$), and mathematics achievement ($t=-734$, $p = .463$). Ajai & Imoko (2015) stated that there was no gender difference in algebraic problem-solving skills.

Gender similarity in mathematics is reached through education by giving equal learning opportunities and educational choices (Catsambis 2005; Halpern et al. 2005). Reviewing and expanding the curriculum to incorporate the needs and interests of a broader range of students is also one of the efforts to address gender similarities in mathematics (Leder 2019).

Gender differences occurred in mathematics because of a stereotype of STEM as a male domain. Based on social learning theory, stereotypes influence competencies, beliefs, and self-efficacy (Lindberg et al. 2010). Parents' and teachers' stereotypes could predict children's perceptions of their competencies (Davies & Spencer 2005). Hence, because of stereotypes and beliefs, females have limited interest in advanced mathematics courses (Catsambis 2005; Davies & Spencer 2005).

Even though they are in opposition to the data, stereotypes and biases still exist (Davies & Spencer 2005; Halpern et al. 2005). Researchers have shown that men score better in math and science, yet more women are entering careers that demand more math proficiency than men (Halpern et al. 2005). However, from a biological standpoint, it makes sense that men performed better in mathematics than women.

Visual-spatial skills are essential in mathematics problem-solving (Halpern et al. 2005). The development of these abilities is affected by hormones and brain structure (Halpern et al. 2005; Zhu 2007). Females having a large corpus callosum were correlated with a lower degree of lateralization (Zhu 2007). The lower degree of lateralization means the left and right hemispheres are more symmetric, which better influences vocal performance. Males have a more lateralized brain structure, which is more crucial for spatial tasks.

Sex hormones also influence the development of the brain. The hormone testosterone found in men decreases the growth of the left hemisphere (Halpern et al. 2005). Due to the right brain's predominance, men typically perform well in various mathematical thinking and spatial tasks.

3 METHOD

The study was conducted on 116 7th-grade students (M age = 13.09, SD = 0.61) in urban (n = 38) and rural (n = 78) areas in East Java, Indonesia. We selected the schools with random classes. A rural school is defined as a school located in the countryside. The participants are homogenous ethnics (95.7% Javanese, 0.9% Batak, and 3.4% Madurese), including 38 boys and 78 girls.

Mathematical problem-solving skills integrated STEM were assessed by using an essay scenario-based problem test. The test is related to the environmental management context. There are three scenarios with a challenge in every scenario. To solve the challenge, students must answer eight prompting questions in every scenario. The prompting questions aimed to explore every step of students' problem-solving process, including understanding information and problems, making hypotheses, designing a prototype, evaluating alternatives, carrying out the plan, and drawing a conclusion. The score of the question is ranged between 0 for a blank answer and 5 for a correct and complete answer. The demographic information was assessed using a questionnaire and a test using an online platform. It includes grade, school location, type, gender, age, and ethnicity. The test and questionnaire were distributed over three hours. The objectivity of data collection (environment, tools, Etc.) was controlled by teachers.

The mean score of students' tests was used as a score of students' problem-solving skills. We analyze using both general and detailed procedures. The general procedure examines the gender and school location differences in mathematics problem-solving skills-based integrated STEM regarding gender and school location. The detailed procedures are: (1) Select each school location and analyze based on gender to find the difference in mathematics problem-solving skills integrated STEM. This phase finds the significant difference between female and male urban school students in performing mathematics problem-solving. The same procedure was applied to rural school students); (2) Select each of the genders and analyze based on school type to find the difference in students' mathematics problem-solving skills-based integrated STEM (e.g., analyze the significant differences between urban and rural schools' male students). To analyze the significant differences in students' mathematical problem-solving skills-based integrated STEM, we applied an independent sample t-test. It was performed by using the SPSS 25 application.

4 RESULTS AND DISCUSSION

The first analysis examined gender differences in students' mathematical problem-solving skills-based integrated STEM among 7th graders. Levene test results were a significant difference, so equal variance is not assumed ($F = 8.05$, $p < .01$). The result was no significant differences between females ($M = 3.02$, $SD = 0.77$) and males ($M = 2.80$, $SD = 1.06$), $t(56.52) = 1.16$, $p = .25$. It means that the school already implemented equal teaching and learning processes, opportunity, and treatment. Each class can only show it for men and women since it still appears in several private schools. Moreover, the task, homework, assessment, facility, and other opportunities were equal. It was supported by several studies that stated there was gender equality in mathematics because of equal opportunities and educational choices (Ajai & Imoko 2015; Halpern et al. 2005; Leder 2019; Nepal 2017).

Regarding the school location, the result of the Levene test concluded that there was a significant difference. The Levene test means that equal variance is not assumed ($F = 7.55$, $p <.01$). The result of the independent sample t-test revealed there were significant differences between urban students ($M = 3.21$, $SD = 2.81$) and rural students ($M = 2.81$, $SD = 0.93$), $t\ (96.483) = 2.58$, $p < 0.05$. Urban school students outperformed rural school students in mathematics problem-solving skills. The result was supported by research that concluded rural school students had lower mathematics achievement and problem-solving skills (Nepal 2017; Ramos et al. 2021; Williams 2005). It could be because of differences in instructional resources, e.g., facilities. Table 1 describes more detailed results of the independent sample t-test.

We will detail the score dispersion and variability in mathematics problem-solving based on gender and school location by using a boxplot in Figure 1.

Figure 1a explains the box plot comparison between females and males in mathematical problem-solving skills based integrated STEM. The black line in the blue box represents a median. The blue box explains the range of data from quartile 1 to quartile 3. The median

Table 1. Result of independent sample t-test on students' mathematical problem-solving skills-based integrated STEM.

	Gender		School location	
	Female	Male	Urban	Rural
N	78	38	38	78
M	3.02	2.80	3.21	2.81
SD	0.77	1.06	0.68	0.93
F	8.05		7.55	
P	.005		.007	
T	1.16		2.58	
Df	56.52		96.483	
P	.25		.01	

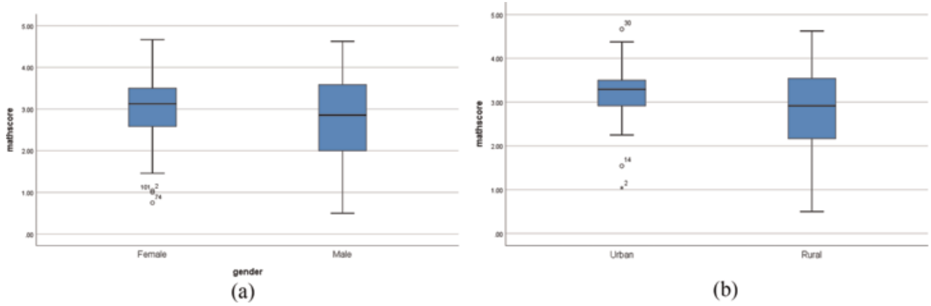

Figure 1. (a) The boxplot of the mathematics problem-solving Score based on gender. (b) The boxplot of mathematics problem-solving score based on school location.

score of females and males were 3.12 and 2.85, respectively. There was a difference between the medians, but they were not significant. 75% of female students' scores were between 2.57 and 3.51.

In comparison, 75% of male students' scores were from 1.97 to 3.62. There were three outlier scores in female participants. The outlier is an observation that lies at an abnormal distance from other values in a random sample of a population.

The outlier increases the variability of data but decreases statistical power, which can be the reason for being statistically insignificant. To determine the outlier, we multiplied the interquartile by 1.5, then subtracted it by quartile one or added it by quartile 3. The result was 1.41, subtracted by quartile 1; we received 1.16. Hence, scores below 1.16 are categorized as outliers. Participants 2, 74, and 101 scored 1.04, 0.75, and 1.00, respectively. These participants might be why the statistics need to be more significant.

The median score of urban and rural students were 3.29 and 2.91, respectively (see Figure 1b). There was a significant difference between the medians. 75% of urban students' scores were between 2.92 and 3.51. In comparison, 75% of rural students' scores were between 2.16 and 3.55. There were two mild outlier scores in urban participants. The score between 2.03 and 4.4 as mild outliers. Participants 14 and 30 had a score of 1.54 and 4.67, respectively. The extreme outlier was detected in participant 2 with a score of 1.04. The extreme outlier is calculated from the interquartile score multiplied by 3. A score below 114 was detected as an extreme outlier.

Since there is a significant difference based on school location, we analyzed which participants contributed to the differences. Hence, we analyzed whether there are significant differences between males (and females) in urban and rural schools performing mathematics problem-solving test-based integrated STEM. The result showed there were no significant differences between males in urban (M = 3.05, SD = 0.78) and males in rural schools (M = 2.66, SD = 1.17) in performing mathematics problem-solving test-based integrated STEM, t(33.541) = 1.22, p = .23. The Levene test showed there was a significant difference, which means that equal variance is not assumed (F = 4.38, $p<.05$). However, there was significant differences between females in urban (M = 3.30, SD = 0.63) and females in rural schools (M = 2.89, SD = 0.80) in performing mathematics problem-solving test based integrated STEM, t(58.844) = 2.43, $p<.05$. Females in urban school outperformed in mathematics problem-solving test based integrated STEM compared to females in a rural school. The Levene test explained there was a significant difference. This test means that equal variance is not assumed (F = 5.04, $p<.05$). Hence, we concluded that the school location difference in mathematics problem-solving skills based on integrated STEM in a whole sample is because of the different skills in female participants. The score dispersion and variability in mathematics problem-solving based integrated STEM score based on school location in each male and female participant is described in Figure 2.

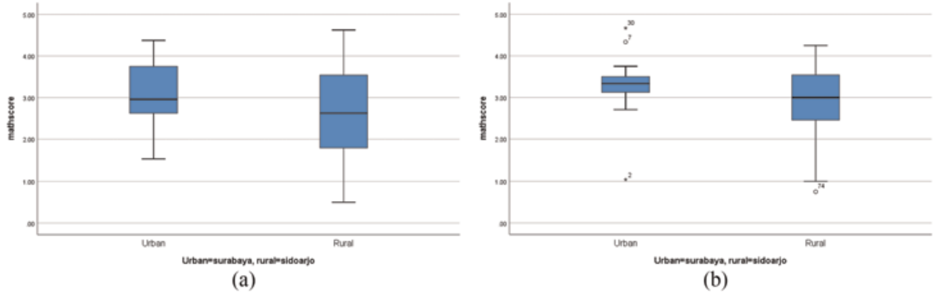

Figure 2. (a) The boxplot of male students' mathematics problem-solving score based on school location. (b) The boxplot of female students' mathematics problem-solving score based on school location.

Figure 2a explains that the median mathematics problem-solving test-based integrated STEM score of male students in urban and rural areas were 2.96 and 2.63, respectively. 75% of male students' scores in urban and rural areas were from 2.52 to 3.79 and from 1.73 to 3.56, respectively. It was obvious that the median score of female urban and rural students was higher when compared to male students, which were 3.33 and 3.00, respectively. The 75% scores of female students from urban and rural schools ranged between 3.10 and 3.5 and between 2.40 and 3.56, respectively. However, there were three outlier scores in female urban school participants. In this case, the mild outlier is a score above 4.1 and below 2.5. The extreme outlier scored above 4.7 and below 1.9.

We hypothesized that if there was no gender difference in mathematical problem-solving in a whole sample, there should be no gender differences in each of the rural and urban school students' mathematics problem-solving skills. To prove it, we conduct an independent sample t-test. Result revealed there were no significant differences between females (M = 3.30, SD = 0.63) and males in an urban school (M = 3.05, SD = 0.78), t(36) = 1.04, p = .31. A similar result was detected in the rural school participants. There were no significant differences between females (M = 2.89, SD = 0.80) and males in rural schools (M = 2.66, SD = 1.17), t(34.881) = 0.88, p = .38. It gave strong evidence that males and females have equal problem-solving skills without considering the school location (Nepal 2017).

The present study has several limitations regarding the sampling method. There is a vast difference number of participants in rural and urban schools; the urban school has a small number of participants. In addition, it is necessary to include participants from more than two different schools to hinder the bias. Moreover, the random sampling method will be better applied to choose the schools.

5 CONCLUSION

The demographic background matters in students' mathematical problem-solving skills based on integrated STEM. However, it cannot be detected in the case of gender in urban and rural schools. There was a difference in the mean of mathematical problem-solving scores based on gender, but the difference was insignificant. The sociological theory wins the argument that there are no gender differences in mathematics performance in the present study. The result contributes to the theory that no gender differences in students' mathematics performance in the 20th century because of similar opportunities in the educational system.

There was a significant difference in mathematical problem-solving skills based on integrated STEM based on school location. Students in rural schools had worse mathematics problem-solving skills-based integrated STEM than students in urban schools. The difference was detected in the female participants, with female students in urban schools outperforming female students in rural schools. The different quality of instructional resources in urban and rural schools was the reason for students' gap in mathematics performance.

There were no gender differences in students' mathematical problem-solving performance, but school location affected it. Hence, the results can be used as basic information for teachers and schools to suppress the reasons for these differences.

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