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by Jurnal Kreano

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Spatial Reasoning of Middle School Students in View of Mathematics Anxiety

Abstract

The low spatial reasoning ability and high mathematics anxiety of junior high school students is an interesting discussion to be studied in more depth to understand students' spatial reasoning abilities and mathematical anxiety. Therefore, this study aims to explore the spatial reasoning abilities of junior high school students in solving geometric problems in terms of students' math anxiety. The research method used is qualitative research with a case study type. Data were collected through written tests to explore spatial reasoning data, followed by task-based unstructured interviews and a Likert scale questionnaire to explore math anxiety data. Furthermore, the research data were analyzed by following the Miles and Huberman model, which consisted of data reduction (data reduction), data presentation (data display), and concluding (verification). The results showed that the average student's math anxiety was 2.294. Students' spatial reasoning abilities were dominated at a moderate level, namely 69.23%. The results also show that the students' spatial reasoning ability does not depend on the math anxiety category. The ability of spatial orientation is the ability most students master. Once the mathematical anxiety and spatial reasoning abilities of students are understood, it is intended that the teacher would take this into account while structuring geometry instruction in the classroom, which will foster the growth of students' spatial reasoning while simultaneously lowering the number of students' mathematical anxiety.

Keywords: Mathematics *Anxiety*, *Spatial Reasoning, Spatial Visualization, Mental Rotation, Spatial orientation*

Abstrak

Rendahnya kemampuan penalaran spasial dan tingginya kecemasan matematika siswa SMP menjadi bahasan menarik untuk dikaji lebih mendalam supaya diperoleh pemahaman menyeluruh tentang kemampuan penalaran spasial dan kecemasan matematika siswa. Oleh karena itu penelitian ini bertujuan untuk mengeksplorasi kemampuan penalaran spasial siswa SMP dalam memecahkan masalah geometri ditinjau dari kecemasan matematika siswa. Adapun metode penelitian yang dilakukan adalah penelitian kualitatif dengan jenis studi kasus. Data dikumpulkan melalui tes tertulis untuk menggali data penalaran spasial dilanjutkan dengan wawancara tidak terstruktur berbasis tugas, dan angket skala likert untuk menggali data kecemasan matematika. Selanjutnya data penelitian dianalisis dengan mengikuti model Miles dan Huberman yang terdiri atas: reduksi data (data reduction), penyajian data (data display), dan penarikan kesimpulan (verification). Hasil penelitian menunjukkan bahwa rata-rata kecemasan matematika siswa yaitu 2,294. Kemampuan penalaran spasial siswa didominasi berada pada level sedang yakni 69,23%. Hasil penelitian juga menunjukkan bahwa kemampuan penalaran spasial siswa tidak bergantung pada kategori kecemasan matematika. Kemampuan orientasi spasial menjadi kemampuan yang paling banyak dikuasai siswa. Setelah kecemasan matematika dan kemampuan penalaran spasial siswa diketahui maka diharapkan dapat menjadi bahan pertimbangan guru dalam mendesain pembelajaran geometri di kelas yang dapat merangsang perkembangan penalaran spasial siswa, pun juga dapat mengurangi tingkat kecemasan matematika siswa.

INTRODUCTION

Spatial reasoning and geometry are two crucial things in child development. Spatial reasoning is a prerequisite for many occupations and is not simply important when learning geometry in a classroom (Ramful et al., 2017). Therefore, the ability of spatial reasoning is essential in life, but students still lack spatial reasoning abilities.

Spatial reasoning, spatial thinking, and spatial abilities are all phrases that are sometimes used interchangeably. According to some research, there is still no consensus on terminologies, definitions, or components (Uttal, Meadow, et al., 2013). Most mathematics education scholars use the term spatial reasoning (Battista et al., 2018; Fujita et al., 2020; Lowrie et al., 2016). According to Mulligan (2015), spatial reasoning is the ability to perceive and manage (mentally) the spatial features of things as well as the spatial connections between these items. Spatial visualization, mental rotation, and spatial

orientation are frequent spatial reasoning components (Lowrie et al., 2019). Lowrie et al. (2019) define spatial visualization as the ability to mentally adjust or control an object's spatial features. Mental rotation is the rotation of 2D or 3D things in the mind (Mix & Cheng, 2012). The goal of spatial orientation is to comprehend and apply the connection that exists between the various locations of objects in space and one's own position (Clements, 1998). Students must take ownership of spatial reasoning because it is crucial for resolving issues in daily life. For instance, to park a car, locate a location using a map, establish oriented in a new place, arrange furniture in the home or office, understand a map's plan, etc. Through the provision of spatial tasks that accommodate all aspects of spatial reasoning, a person's spatial reasoning capacity can be determined. Spatial reasoning skills can also be developed (Uttal, Meadow, *et al*., 2013; Uttal, Miller, *et al*., 2013) through proper learning and can be practiced starting in the early years of school.

Several research findings indicate that students' spatial reasoning abilities are still low. Both at the National and International levels. At the elementary level, students' spatial skills are still relatively low (Kurnila et al., 2019; Wulandari, 2019). Likewise, the student's spatial ability in junior high school (Adam & Zulkarnaen, 2019; Akbar, 2019; Cahyati & Risalah, 2021; Leni et al., 2021) and students in high school (Afriyana & Mampouw, 2019; Imaniar et al., 2021; Novitasari et al., 2021; Perangin-angin & Khayroiyah, 2021; Rahmatulwahidah & Zubainur, 2017; Thohirudin et al., 2017). Low spatial abilities were also found in mathematics education students in Aceh (Daulay et al., 2021). At the international level, several studies have also shown that students' spatial abilities from school (Carr et al., 2018; Möhring et al., 2021; Sorby & Panther, 2020) to tertiary institutions are still low (Toptas & Karaca, 2017).

The low spatial ability of students both at the national and international levels has an impact on students' geometry abilities. In contrast, geometry is part of mathematics which further reinforces the perception that mathematics is imaged as a complex subject. Many factors cause students' learning achievement in mathematics is still low. Among them is the affective aspect. One of the affective aspects that can affect math achievement is math anxiety (Berliana & Adirakasiwi, 2021; Skagerlund et al., 2019). Math anxiety concerns mathematics situations (Carey et al., 2017). Furthermore, Zhang (2022) divides math anxiety into math anxiety in class, math anxiety when taking tests, math anxiety in problem-solving, and anxiety about the feeling of math as a whole. The aspects of math anxiety that are combined from various perspectives include social phobia (Lowe, 2018), disliking mathematics (Ashcraft, 2002; Wilson, 2018), physical symptoms (Harari et al., 2013; Lowe, 2018; Wilson, 2018), anxiety (Harari et al., 2013; Lowe, 2018), avoiding mathematics (Ashcraft, 2002; Wilson, 2018), and cognitive impairment (Lowe, 2018). Strong concentration and focus are required when performing tasks that call for spatial reasoning skill. Students who struggle with math anxiety may find it harder to focus and pay attention, which will ultimately affect their ability to use spatial reasoning.

The results of previous research indicate that the math anxiety experienced by junior high school students (Berliana & Adirakasiwi, 2021; Fadilah & Munandar, 2020; Prahmana et al., 2021; Utami & Warmi, 2019); high school students (Adhimah & Ekawati, 2020; Juliyanti & Pujiastuti, 2020; Khoirunnisa & Ulfah, 2021; Kusmaryono & Ulia, 2020; Nurjanah & Alyani, 2021; Supriatna & Zulkarnaen, 2019)

and even university students (Prahmana et al., 2019; Purnomo & Loekmono, 2020) are in the high category. At the international level, math anxiety is a hot issue that researchers are also studying. Several studies report that students' math anxiety is still high (Mutlu, 2019; Orbach et al., 2019; Wang et al., 2020), including adults' math anxiety (Hart & Ganley, 2019).

The low spatial reasoning ability and high mathematics anxiety of junior high school students is an interesting discussion to be studied in more depth to understand students' spatial reasoning abilities and mathematical anxiety. Therefore, this proposed research aims to explore the spatial reasoning abilities of junior high school students in solving geometric problems in terms of students' math anxiety. The purpose of this study is to investigate students' spatial reasoning skills in relation to their level of mathematics anxiety, which will give a general summary of the traits of students' spatial reasoning skills. The features of spatial reasoning ability are predicted to influence mathematical skills in general and understanding of geometric concepts in particular. In addition, the urgency of this research can also provide an overview and knowledge for teachers in designing geometry learning designs that accommodate spatial reasoning abilities and minimize their math anxiety.

METHOD

This study used a qualitative approach with a single case design embedded case study design (Creswell, 2015). One of Yogyakarta's Muhammadiyah Middle Schools serves as the research site. Subjects were taken from class VIII students consisting of 55 students. Students initially took part in completing a Google form-based survey about their math anxiety. The 36 statements that make up the math anxiety questionnaire address three different types of math anxiety: learning mathematics, assessing mathematics, and social mathematics. Each type of math anxiety is composed of two statements that address different components of math anxiety, such as social fear, avoidance to mathematics, negative impressions of mathematics, physical symptoms, anxiety, and cognitive impairment. The results of the math anxiety survey were then processed using Microsoft Excel to be classified into three categories: high, medium, and low levels of math anxiety. Several students were taken at each level of math anxiety and then given a spatial reasoning ability test. Subject-taking at each level of mathematical anxiety was stopped until the data on the students' spatial reasoning ability was saturated.

We used written tests, interviews, and questionnaires in addition to collecting data. The purpose of the written test is to retrieve student spatial reasoning ability. The spatial reasoning test utilizes the Ramful (2017) spatial reasoning test, which consists of 30 multiple-choice questions, ten drawn from each of the three elements of spatial reasoning: mental rotation, spatial orientation, and spatial visualization. Following that, several individuals were chosen for additional interviews to examine students' spatial reasoning data from a range of math anxiety levels and based on the math teacher's considerations. To uncover participants' spatial reasoning skills that had not been further examined from the findings of the spatial reasoning test, the interviews were done in an unstructured and face-to-face task-based way. Test the credibility of the data using source triangulation.

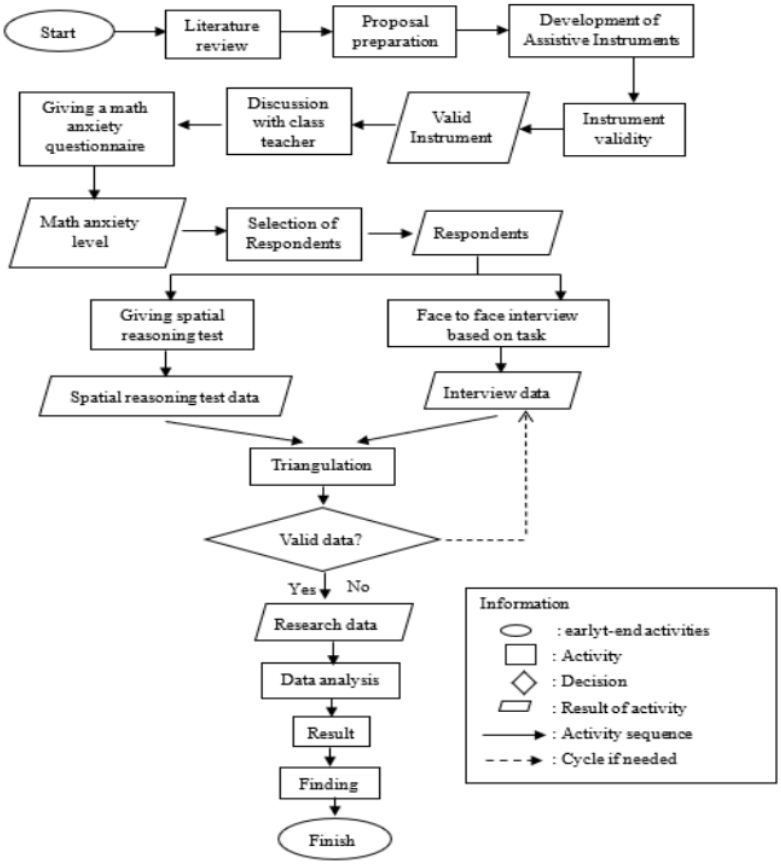

Figure 1. Research Stages

The procedure for analyzing qualitative research data follows the model of Miles and Huberman (Miles et al., 2014), which consists of data reduction, data display, and conclusion drawing. A reduction process was then carried out with qualitative data from data collection techniques using tests and interviews. The reduction process was obtained after the data was checked, extracted, and entered word for word, then coded independently by the researcher. Next, the researcher carried out the process of reviewing the validity of the data by triangulating the data. The results of data triangulation are then presented in the form of tables, diagrams, and or narratives as a basis for carrying out the process of concluding (verification). The stages of the research are presented in the following figure 1.

RESULTS AND DISCUSSION

Results

The data obtained in this study included math anxiety data obtained through closed and open questionnaires to explore the causes of students' math anxiety. The spatial reasoning data was obtained through a written test using multiple choices. Mathematics anxiety data is qualitative data, then converted to numeric and then processed with the help of

Microsoft Excel to become a percentage. Qualitative data in the form of students' assessment of their math anxiety in the form of strongly agree, agree, disagree, and strongly disagree. Because the questionnaire statements include statements with negative values, the conversion becomes strongly agree (4), agree (3), disagree (2), and strongly disagree (1).

The math anxiety questionnaire was given online via Google form, and as many as 40 students participated in filling out the math anxiety questionnaire. The following Figure 2 describes student participation in filling out the math anxiety questionnaire.

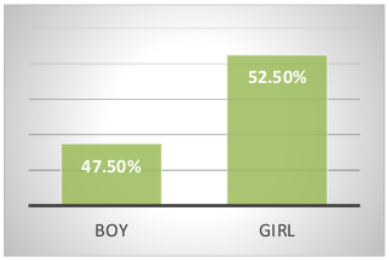

Figure 2. Percentage of student engagement

Most students stated that they had experienced math anxiety. Figure 3 shows the percentage of students who have experienced math anxiety.

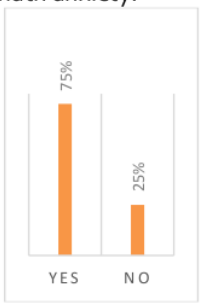

Figure 3. Percentage of students experiencing math anxiety

The math anxiety experienced by students started not only in the current class, but some students stated that they had experienced math anxiety since they were in elementary school. A complete description of the first-time student's experiences with math anxiety is presented in Figure 4.

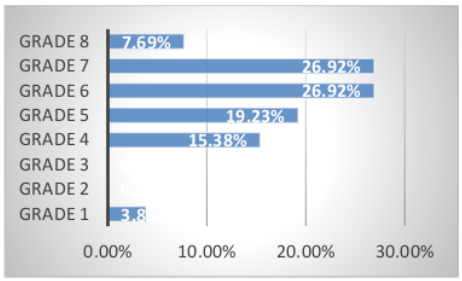

Figure 4. Students experienced math anxiety at first

In this research, math anxiety is divided into three types, namely: math anxiety in learning mathematics, evaluating mathematics, and social mathematics (Núñez-Peña et al., 2013; Recber et al., 2018; Semeraro et al., 2020; Skagerlund et al., 2019; Zakariya, 2018; Zhang, 2022). The results of data analysis of math anxiety on the type of learning mathematics are presented in Figure 5 below. Overall, the average math anxiety during learning mathematics is 2.49.

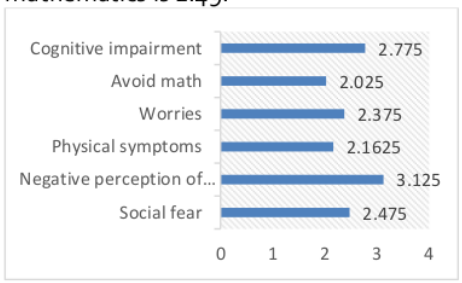

Figure 5. Average of students' math anxiety when learning mathematics

The second type, namely mathematical anxiety on the kind of mathematical evaluation presented in Figure 6 below. The overall average of students' anxiety during the mathematics evaluation was 2.56.

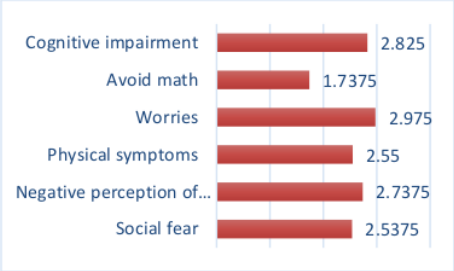

Figure 6. Average of students' math anxiety on mathematics evaluation

In the third type of math anxiety, social mathematics, the study results show that the average student anxiety varies, as shown in Figure 7 below. The average student's math anxiety on the social math aspect is 2.64.

Figure 7. Average of students' math anxiety is social mathematics.

Based on the results of the research on math anxiety described above, it can be said that overall, the average student's math anxiety is 2.56 or still in the good category. The average mathematics anxiety in each type, namely mathematics anxiety in the type of mathematics learning, reached 2.49, the kind of mathematics evaluation showed average mathematics anxiety of 2.56 and the type of social mathematics earned 2.64. From this, it can be concluded that students are most anxious when dealing with situations involving mathematics in life or social mathematics.

In addition to the 3 types of math anxiety as described above, there are six aspects of math anxiety used in this study, namely social fear, negative perceptions of mathematics, physical symptoms, worry, avoiding mathematics, and cognitive impairment (Grezo & Ivan Sarmany-Schuller, 2018; Lowe, 2018). The results revealed that the average student's math anxiety was highest in the element of negative mathematical impressions, precisely 2.90.

Using descriptive statistics, subsequently divided the students' math anxiety data into three groups: high, medium, and low. From the calculation results, it was found that there were six students in the high category (15%), 27 students in the medium category (67.5%), and seven students in the low category (17.5%). Most students are in the category of moderate math anxiety. Furthermore, of the 40 students who filled out the math anxiety questionnaire, only 26 students had valid data for spatial reasoning abilities.

Of the 50 students who took the spatial reasoning test, after being reduced by considering the completeness of the answers to the 30 questions on the spatial reasoning test and their participation in filling out the math anxiety questionnaire, only 26 students met the criteria for further analysis. Of the 26 students, 10 were boys and the rest were girls. The data reduction results showed that there were 4 students in high math anxiety, 19 in the medium category, and 3 in the low category. As for the category of spatial reasoning ability, one student included high, 18 students had moderate, and the rest seven students included in the low category. Figure 8 below presents the categorization of students' spatial reasoning abilities.

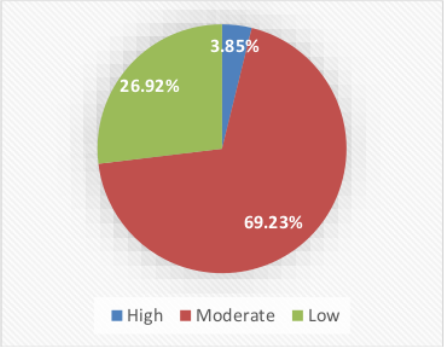

Figure 8. Category of students' spatial reasoning abilities

Figure 8 shows that the medium category still dominates students' spatial reasoning abilities. Of the 26 students, it turned out that only one student had high-category spatial reasoning abilities. The level of spatial reasoning ability is still dominated at the moderate level, namely 69.23%. As for gender, the average correct answers of male and female students on the spatial reasoning test showed nearly the same results. The average correct answer for male students was 12.2 and for female students was 12.75. This means that as many as 12-13 questions were answered correctly by the students.

Judging from the category of math anxiety, students' spatial reasoning abilities are not inversely proportional to the category of math anxiety. All students who are in the category of high math anxiety have the moderate category of spatial reasoning abilities. Students in the math anxiety medium category are at moderate and low spatial reasoning abilities. Students in the low math anxiety category have high, medium, and low spatial reasoning abilities. From this, it can be temporarily concluded that high math anxiety does not necessarily make students have low spatial reasoning abilities. More complete results can be seen in Figure 9 below.

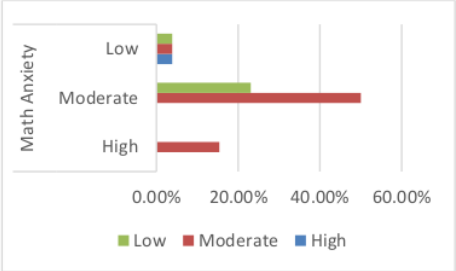

Figure 9. Distribution of spatial reasoning ability based on math anxiety category.

Three skills—spatial orientation, mental rotation, and spatial visualization—combine to form spatial reasoning. The findings of the spatial reasoning exam revealed that, on average, pupils correctly answered 6.77, or between 6-7 questions, regarding spatial orientation. While the second construction of spatial reasoning that students sufficiently master are the mental rotation type test, which is about 2-3 questions answered correctly or an average of 2.92. Likewise, the type of spatial visualization questions with an average correct answer of only 2.85 or 2-3 answered correctly.

Interviews were conducted for one day with a group interview design. Each participant was interviewed for about 30 minutes. The interviews result for triangulation data revealed that in carrying out spatial reasoning tests, students found it easier to do tests related to simple spatial orientations, such as determining the location of an object and showing pictures of objects from another person's point of view. But for this type of spatial orientation test regarding plans and the location of places on a map, most students are still confused about reading a map or finding the site of a place. For the type of spatial visualization questions, most students also still have difficulty doing it correctly. Students tend to imagine the pictures presented to find the answer. For mental rotation questions, some students tried to demonstrate rotating the question paper

or making another image demonstration from the article. This method is considered quite effective in helping students find answers to questions. Some students also stated that they did not understand the terms used in the questions, so they answered them randomly.

Discussion

The results of the research described above show that mathematics anxiety and spatial reasoning abilities of students were vary. Many students' math anxiety is still at a moderate level, namely 72.5%. These results show that most eighth-grade students have moderate levels of math anxiety, which is consistent with their overall feeling of concern about mathematics. This data is in keeping with Yuliani's (2019) assertion that more than 85% of the class's junior high school students, who are in grades VII through IX, had moderate levels of math anxiety. In addition, these results also support the findings of Fadilah (2020) which states that most students have math anxiety at a sufficient level of the four levels used. Likewise, it supports the findings of Nurjanah (2021) which states that as many as 73.78% of students have math anxiety in the moderate category.

According to the forms of math anxiety examined in the study—including anxiety related to learning mathematics, anxiety related to mathematics evaluation, and anxiety related to social mathematics—students exhibit the highest anxiety when dealing with situations in life that require the use of mathematics. These findings different from Nurjanah's findings (2021) that junior high school students frequently experience high levels of anxiety when learning mathematics, despite the fact that Nurjanah places more emphasis on mathematics anxiety in online learning while this study's participants engage in offline learning. This is still pertinent considering how students are faring when they switch from online to offline schooling during the post-pandemic transition phase.

From the aspect of math anxiety which consists of six aspects, namely cognitive impairment, avoiding mathematics, anxiety, physical symptoms, negative perceptions of mathematics, and social fear, the research findings show that the highest average anxiety is on negative perception aspects of mathematics, namely 2.90, while the lowest average anxiety on the aspect of avoiding mathematics. This finding indicates that most respondents still have a negative perception of mathematics that triggers anxiety when interacting with mathematics both in class and in everyday life. Even so, the research data shows that respondents still want to interact with mathematics, as indicated by the average score of the aspect of avoiding mathematics, which is at the bottom.

The level of spatial reasoning ability of students yielded a variety of results. According to the findings, the level of students' spatial reasoning ability was dominated at the moderate level, namely 63.29%. These support the findings Fitriyani (2021; 2022) with junior high school students as subjects. The results of this study also inform that very few students have achieved high-level spatial reasoning abilities, namely, only one female student. This finding is in line with the results of Leni (2021) that students with a high spatial reasoning ability are still few in class. In addition, students with the female gender have high-level spatial reasoning abilities, thereby demonstrating that male and female pupils often exhibit different spatial thinking skills. This finding contradicts the notion that spatial rea-

soning abilities differ by gender (Newcombe, 2010). Furthermore, several research findings state that male students often have stronger spatial reasoning skills than female ones (Fitriyani & Kusumah, 2022; Maeda & Yoon, 2013; Moè et al., 2020; Ramful & Lowrie, 2015; Reilly & Neumann, 2013; Vander Heyden et al., 2016; Zancada-Menendez et al., 2016). In contrast, Newcombe (2010) stated that the spatial reasoning abilities of female students were better than male students. It is different from his findings (Fitriyani et al., 2021; Lowrie et al., 2016) which state that the spatial reasoning ability of the students are not gender-specific.

The research findings show that high math anxiety does not necessarily mean students have low spatial reasoning abilities. Students in the low math anxiety category have low spatial reasoning abilities. Even though the students were not worried, it turned out that their spatial reasoning abilities were still down. This is probably caused by other factors, such as understanding the concept of geometry and other factors because math anxiety does not bridge the relationship between spatial ability and math performance (Likhanov et al., 2017).

When considered from the perspective of the elements that make up the creation of spatial reasoning, including mental rotation, spatial visualization and spatial orientation, the research findings show that spatial orientation ability is an ability that most students have well. Students tend to be able to do well on spatial orientation tests. This finding supports the results of Leni's research (2021), which found that most students properly responded to the spatial orientation question of the spatial reasoning test. Likewise, it supports the findings of Latifah (2019), in which the research subjects experienced no difficulty working on the spatial orientation test.

The construction of spatial reasoning in the spatial visualization and mental rotation sections is almost the same as being mastered by the students. The results of the students' answers showed similar scores for the two constructions, but students' mental rotation abilities tended to be slightly better than spatial visualization abilities. Some students demonstrated by rotating the sheet of paper to imagine the object's final position after being rotated. This method is considered easier than rotating objects in mind. This follows the level of development of class VIII students who are just passing through the concrete operational stage and starting to enter the abstract operational stage (Ibda, 2015). Students find it easier to use physical objects in front of them to work on spatial reasoning questions.

The spatial visualization ability test is the most challenging test for students. Students have difficulty imagining objects to work mentally to process the information provided. This result is different from Pradana's findings (2019), where non-autistic students have superior concrete spatial visualization abilities while autistic students are more prominent in abstract spatial visualization abilities. Spatial visualization tests generally require students to be skilled at using their reasoning. Fitriyani's findings (2022) state that students view, observe, and pay attention to the things given as they complete their spatial visualization projects. The activity of imagining is a critical point for the successful completion of a spatial visualization task. Spatial visualization tasks include mentally imagining how an item will change (Ramful et al., 2015). Furthermore, To perform spatial visualization assignments, students employ visual methods (Fitriyani & Kusumah, 2022).

In completing the mental rotation task, students do more demonstrations or demonstrate the rotation of an image in

completing the mental rotation test. Even though mental activity is still being carried out, students find it easier to find results by demonstrating concrete objects. This finding is different from the findings (Fitriyani & Kusumah, 2022), which state that students use things to mentally rotate as a justification for performing mental rotation exercises. In the spatial orientation task, it is easier for students to find the answer because this task is closer to the student's daily life. Students put themselves in the position of the object in the task given. This method follows Fitriyani's research (2022) results because Imagine viewpoints from different locations as part of spatial orientation (Lowrie et al., 2020).

Implication

Future study can focus on developing students' spatial reasoning skills while also lowering math anxiety among students by implementing learning models that assist the development of students' spatial reasoning skills.

Limitation

The subjects of this study were only students in one school with a qualitative approach, so the research results could not be generalized. In addition, online math anxiety data collection allows respondents not to take the questionnaire seriously. The study's findings on students' spatial reasoning skills dependent on their level of math anxiety are still in the exploratory stage.

CONCLUSION

The student's spatial reasoning skills varied, but they were moderately predominating—69.23%. The ability to visualize objects spatially is the one that students are least proficient in out of the three elements of spatial thinking. Students find it challenging to mentally construct objects to process the information given. The skill that many pupils have mastered the most is spatial orientation. Students find it simpler to complete activities requiring mental rotation with the aid of concrete object demonstrations. Additionally, class VIII students' mathematics anxiety dominated the moderate category with an average of 2.294 at maximum score of 4. The results of the study demonstrate that students' capacities for spatial reasoning are independent of their level of mathematics anxiety. Students who struggle with mathematics anxiety may not always be bad at spatial reasoning.

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