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The relation between teacher and students' mathematical mindsets to the student's comprehension of mathematics concepts

Sugama Maskar[1,2,*], Tatang Herman[1]

[1]Mathematics Education Department, Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Mathematics Education Department, Universitas Teknokrat Indonesia, Lampung, Indonesia
*Correspondence: sugama_maskar@teknokrat.ac.id

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Abstract

The aim of this study is to understand the relationship between teacher and student mindsets in relation to the student's comprehension of mathematics concepts. This study used a qualitative research type with a case study method. Participants in this study were 30 students and one teacher from one of the public junior high schools in Cianjur, Indonesia. Data sources used in this study were collected through teacher and student questionnaires, class observations, and semi-structured interviews. The class observation material was about linear function, and the learning process was carried out using the Complex Instruction (CI) approach based on growth mindset instruction. The questionnaire results show that teachers and students tend to have a fixed mindset. The fixed mindset of both the students and the teacher is particularly evident in their beliefs about the nature of math and their orientation towards student mastery and performance. The results of observations and interviews show a relationship between this mindset and student performance in class. Most students tend to show low performance in understanding linear function concepts. Based on the observations, students experienced problems in algebra thinking, had difficulty understanding mathematical concepts as a whole, and showed a lack of motivation and self-confidence. The results indicate that there is a significant relationship between the fixed mindsets of teachers and students towards students' lower performance in mathematics learning in the classroom.

Keywords: Case Study, Fixed Mindset, Growth Mindset, Mathematical Mindset

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Mathematics has long been regarded as a discipline devoid of creativity, as a set of rules and procedures that must be memorized (Selbach-Allen et al., 2020). Most students perceive mathematics as dealing with short questions that require correct answers. They need to recognize mathematics as a collection of ideas and concepts that involve exploring a network of connections and engaging in deep creativity, as mathematicians do (Boaler, 2022; Selbach-Allen et al., 2020).

Students' negative perceptions of mathematics contribute to developing a fixed mindset. Students' perception of mathematics is cited as the primary reason for their negative attitude toward the subject (Aguilar, 2021). Due to this mindset, students become less motivated and need more control over their learning, resulting in a belief that they can excel in other subjects but not in mathematics (Boaler, 2022; Jaffe, 2020).

Students with a fixed mindset tend to stop asking questions and lose focus. This fixed mindset instills fear of mathematics, hindering students' ability to succeed in learning the subject. They become stressed and develop a negative self-identity, believing they can learn anything except how to improve their fundamental intelligence (Boaler, 2022; Boaler & Sengupta-Irving, 2016; Dweck, 2006). This fear causes students to give up more quickly without giving themselves a chance to learn. This is particularly common among students learning mathematics, as they often connect their difficulties in learning mathematics with a lack of intelligence and a belief that they cannot learn mathematics (Avvisati et al., 2018; Boaler & Sengupta-Irving, 2016). Mathematics is correlated with low achievement in the subject. In general, students believe that mathematical knowledge is unchangeable, and they acquire this belief from teachers and textbooks (Boaler, 2019a, 2022; Muis, 2004).

Indonesian students need higher achievement in mathematics. Indonesian students' low achievement in mathematics is evident in the results of the Programme for International Student Assessment (PISA) in 2018. According to information from the website www.oecd.org, PISA is a program conducted by the Organization for Economic Co-operation and Development (OECD) to assess 15-year-old students' knowledge and skills in reading, mathematics, and science in real-life contexts. The low PISA scores in Indonesia are indicated in Figure 1 (Avvisati et al., 2018).

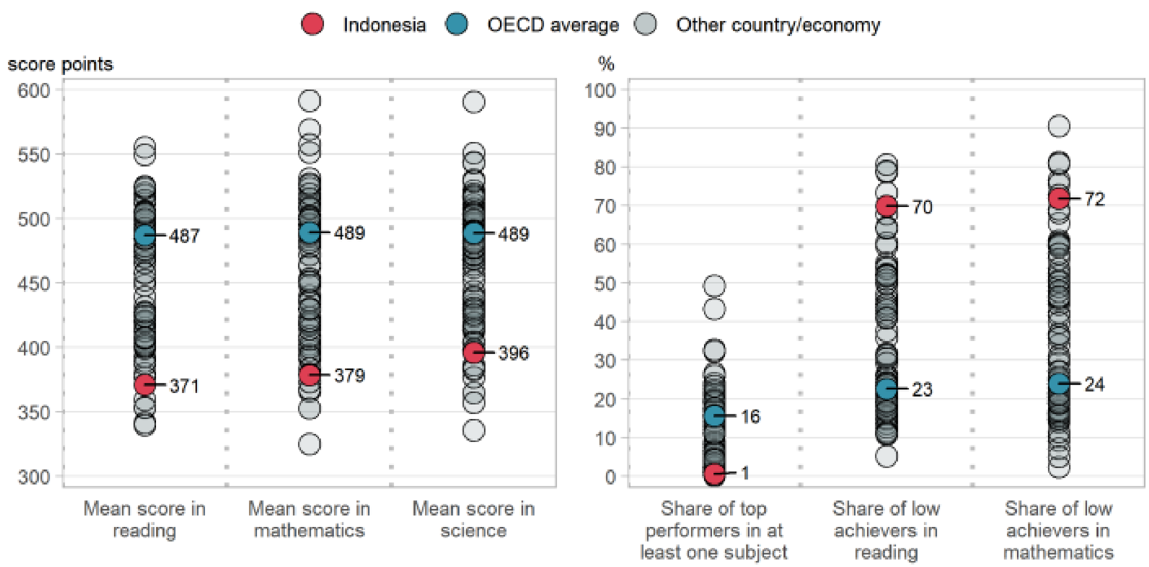

Figure 1. Reading, Mathematics, and Science proficiency of Indonesian students in PISA 2018

Figure 1 shows that the average PISA scores of Indonesian students are below the international average for all tested subjects. One percent (1%) of the sampled Indonesian students fall into the high proficiency category, Levels 5 and 6. However, 72% of them exhibit low proficiency in mathematical literacy. This result concerning mathematical literacy indicates that most Indonesian students cannot mathematically model complex situations, meaning they need help selecting, comparing, and evaluating appropriate problem-solving strategies for such complex situations.

Research on low PISA scores indicates several vital factors, including growth mindset and students' economic and cultural status (Aguilar, 2021; Kane & Mertz, 2012; Setiawan et al., 2021). This means that psychological factors are fundamental in determining students' mathematical achievement. Students with a negative perception of mathematics tend to perform poorly in the subject (Rahardi & Dartanto, 2021; Setiawan et al., 2021). Psychological factors are related to self-efficacy, which refers to one's belief or confidence in their ability to succeed in learning mathematics. Self-perception related to mathematics is the first barrier that students encounter in learning mathematics and contributes to negative attitudes. This is because students recognize their lack of foundational knowledge in mathematics as a result of their initial perception of the difficulty of mathematical reasoning (Aguilar, 2021; Aswin & Herman, 2022; Boaler et al., 2022; Nurita et al., 2022). Self-efficacy is part of the mindset (Rhew et al., 2018), meaning that students with a growth mindset are more likely to learn mathematical knowledge, actively engage in the learning process, and creatively connect mathematical ideas. Conversely, students with a fixed mindset face significant barriers in initiating mathematical learning, as experienced by the majority of students in Indonesia (Kane & Mertz, 2012; Setiawan et al., 2021; Rahardi & Dartanto, 2021).

Incorporating the idea of a growth mindset in mathematics education is crucial. Research considering the impact of mindset on mathematics learning in the classroom has shown significant positive effects (Anderson et al., 2018; Boaler, 2019b; Boaler et al., 2021, 2022; Lee et al., 2019). Several studies have found that students with a growth mindset in mathematics tend to find innovative ways to solve problems. If they are successful, they will seek additional questions and consult books or online resources to gain ideas. This helps deepen students' mathematical knowledge because they perceive their mathematics learning as more meaningful (Boaler et al., 2022; Henningsen & Stein, 1997; Masitoh & Fitriyani, 2018). Furthermore, a growth mindset encourages students to seek clarification when unsure. Moreover, this mindset fosters confidence and self-belief in mathematical knowledge, thereby enhancing mathematics learning achievement (Aswin & Herman, 2022; Jaffe, 2020).

In other studies, it has been found that a mathematical mindset is related to motivational factors, self-confidence, perception, students' knowledge, and interest, as well as teacher support (Aguilar, 2021; Boyer & Mailloux, 2015; Hannula et al., 2004; Heinze et al., 2005; Tambunan, 2018). Research on the effectiveness of mindset interventions, which instill the idea that intelligence can be developed and that effort is an essential part of learning, has been conducted across different age groups and subjects, highlighting its importance (Blackwell et al., 2007; Boaler et al., 2022; Dweck, 2006). When students change their mindset and believe they can learn at higher levels, they alter their learning trajectory (Boaler et al., 2022).

Individuals with a growth mindset believe that their intelligence can be developed through hard work (Blackwell et al., 2007; Dweck, 2006, 2007; Uwerhiavwe, 2023). Students with a growth mindset see failures as learning opportunities. They are persistent, set long-term goals, and are willing to face challenges. Additionally, students with a growth mindset always strive to improve upon their previous performance, which requires them to step out of their comfort zones and commit to learning (Duckworth, 2016; Dweck, 2006; Jaffe, 2020; Miller & Gerlach, 1997; Pink, 2011). Students with a growth mindset tend to ask questions until they gain a meaningful understanding of the material. They exhibit a proactive attitude in seeking relevant resources, demonstrate a desire for advancement in the classroom, and enjoy the learning process (Jaffe, 2020).

The implementation of mindset interventions should also consider the phenomenon known as false growth. False growth is when teachers apply mindset ideas to students but do not see any significant impact. While several studies have shown changes in students' mindset toward mathematics, there are critiques regarding its implementation in the classroom. When teachers solely focus on motivation, praising effort, and instilling beliefs in students without implementing effective instructional strategies, students' mathematical reasoning abilities may not significantly improve. This occurs when students receive feedback or experience teaching practices that are similar to what they have previously encountered (Boaler et al., 2021).

It is important for teachers to not only focus on changing mindsets but also to create an environment that supports learning. Simply altering students' mindsets without changing the learning environment can be detrimental and potentially place the entire responsibility on the students. Therefore, mindset interventions should not be limited to mindset alone but should also consider the learning environment (Boaler et al., 2022; De Kraker-Pauw et al., 2017).

If students are given a mindset intervention that promotes the idea that they can learn anything but then are confronted with closed-ended questions in mathematics learning that do not allow them to develop their ideas, the effectiveness of the mindset intervention is often compromised, and may not yield significant results (Boaler et al., 2022; LaMar et al., 2020; Li & Bates, 2019). Creating an inclusive and engaging learning environment that provides students with opportunities to develop their mathematical thinking and actively participate in the learning process is crucial. Figure 2 depicts a visual representation that encapsulates the concept of math teaching aligned with a growth mindset. It integrates insights from psychological principles and mathematics education (Sun, 2015).

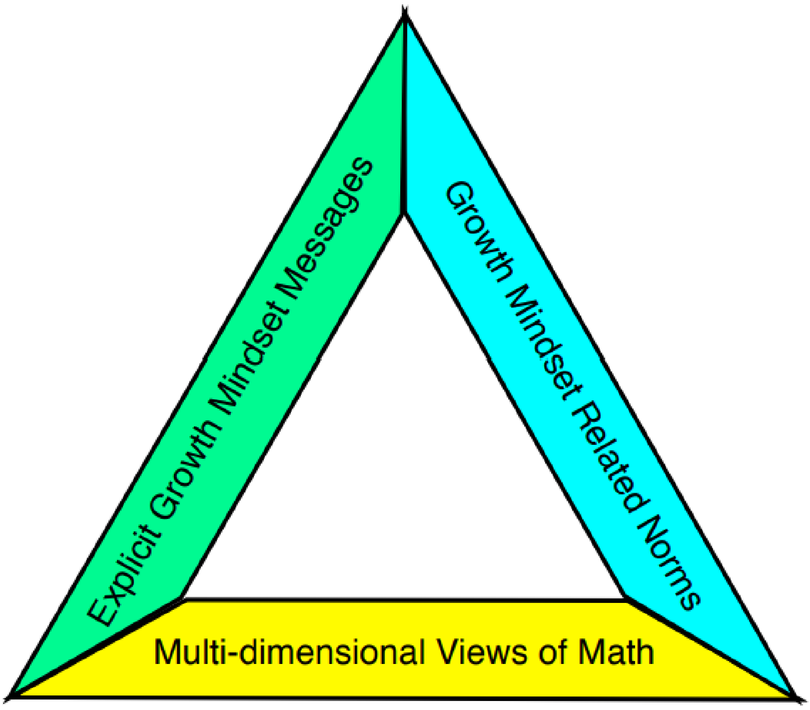

Figure 2. Growth Mindset Math Instruction

False growth occurs as a result of the lack of academic support following previous mindset interventions because the essence of the growth mindset concept is to encourage and appreciate students' efforts, which can be achieved by assigning challenging yet attainable complex tasks accompanied by positive messages from the teacher that students are capable of completing the tasks and that every effort will be valued (Boaler et al., 2022; Moser et al., 2011). The struggle students face in completing complex tasks should cultivate resilience and perseverance, also called grit, so that possessing a growth mindset does not become the sole predictor of students' mathematical achievement (Duckworth, 2016; Jaffe, 2020).

Based on this explanation, this study examines the relationship between the teacher's and student's mathematical mindset on student performance in mathematics learning, specifically toward understanding the concept of linear functions. In addition, this study also aims to reveal actual problems related to the mindset of teachers and students related to the learning strategies used by teachers in the learning process in the classroom and their relationship with student performance in learning mathematics.

METHODS

Research Design

This study utilized a qualitative research methodology and adopted a case study approach. A case study is a type of research that uses qualitative methods and focuses on a single social phenomenon, requiring an in-depth investigation of that phenomenon. Case studies involve using multiple data sources to understand a particular phenomenon (Crowe et al., 2011; Feagin et al., 2016; Heale & Twycross, 2018).

This study employed case studies as its primary method to understand the relationship between teacher and student mindset toward understanding linear function concepts by analyzing junior high school students' learning experiences while studying linear function.

The authors limited this study's discussion scope to the basic concept of single-variable linear functions. Two main reasons underlie the selection of this material. The first reason is that the concept of single-variable linear functions is one of the crucial concepts after algebraic material to be able to study further topics in both junior high school and high school mathematics. According to Pierce, et al. (2010), understanding linear functions is highly important for students to develop a strong foundation in algebra. Students should learn about variables (x and y) and parameters (m and c), as well as the function of each element in the general linear function rule $y = mx + c$. The analysis of linear functions includes discussing the structure of function spaces and the properties of continuous mappings between these spaces, from the basic concept of Euclidean Space to generalizations in function spaces (Alt, 2016).

According to Postelnicu (2011), on the topic of linear functions, problems that require identifying the slope of a line graph are the most challenging for students at all levels. Furthermore, Birgin (2012) discovered that some students experience difficulties and misconceptions regarding equations, graphs, and the slope of linear functions, and they need help comprehending the relationship between the slope and the points of intersection on the x and y axes.

Participants

This study was conducted at one of the Public Junior High Schools in Cianjur in May 2023. The sample for this study was selected using a purposive sampling technique (Etikan et al., 2016; Rai & Thapa, 2015). The participants in this research included one mathematics teacher, 30 students from the 8th grade who were present during classroom observations, and 26 who were willing to fill out the questionnaire. The students ranged in age from 12 to 14 years. On the curriculum in Indonesia, these students had already completed basic algebra and linear equation subjects. Students study the material in their first year of junior high school.

Case Study Overview

Teacher Belief Measure

The measurement of teachers' confidence in mathematics was assessed using a questionnaire consisting of 40 items (Sun, 2015). The questionnaire was given to the mathematics teacher in charge of the class whose students were the subject of this study. These 40 items measured four belief constructs, including teacher-reported practice items, teacher mindset, teacher expectations, teacher beliefs about the nature of math, and teacher-access views of math. The survey questions were assessed using a scale that ranged from 5 points, indicating the perceived importance, to a 6-point scale, indicating the level of agreement (Sun, 2015).

Student Belief Measure

The students whose teachers were surveyed were administered an 18-item questionnaire to assess their beliefs pertaining to mathematics. The questionnaire aimed to measure four belief constructs: mindset, beliefs regarding the nature of mathematics, performance orientation, and identification with mathematics (Sun, 2015). After the learning process was carried out in class, questionnaires were given to students.

The construct of student mindset included three items (Q5, Q9, and Q11) measured on a six-point scale ranging from agree to disagree. These items were employed to evaluate student beliefs regarding their mathematical abilities. Student beliefs about the nature of math were assessed using a construct consisting of three items: Q4, Q6, and Q8. These items were specifically designed to measure student beliefs regarding the fundamental characteristics of mathematics. Student mastery orientation, as opposed to performance orientation, was evaluated through a set of four items (Q15, Q16, Q17, and Q18). These items focused on students' perceptions of behaviors associated with performance-oriented approaches, such as making mistakes or achieving correct answers. Student identification with math was assessed using a set of four items: Q10, Q12, Q13, and Q15. These items were utilized to measure the extent to which students identified with mathematics.

There were four statement items that were dropped due to their contradictory results with the other three statements. These four statements were Q1, Q2, Q3, and Q7. These three statements were chosen to be excluded from measuring students' beliefs because their results needed to reflect the existing facts based on confirmation from similar statements, observations, and student interviews.

Classroom Observation

The classroom instruction was conducted using the complex instruction (CI) approach based on the theoretical perspective of growth mindset math instruction (Cohen et al., 1999; Kane & Saclarides, 2022; Sun, 2015). The implementation of the learning process for this study, adopting CI in general, consisted of group exploration, intergroup discussions, and reflection. In this study, the learning process in the classroom was carried out directly by the researchers with the aim that the strategies used could effectively measure students' mathematical mindsets. Things that were observed in the observation process included class activities consisting of interactions between the teacher and students on the worksheets given. Besides that, observations were also made related to the activities of students and students in their groups and interactions with other groups. Furthermore, observations were also made to determine student performance in solving problems on the worksheet. This observation aims to find out the students' actual problems based on the theory of growth mathematical mindset.

Interviews

Semi-structured interviews were conducted (Magaldi & Berler, 2020; Schmidt, 2004) with one teacher and three students, which were recorded and transcribed. Three students who were interviewed were selected based on their group performance during the learning process, which consisted of students who experienced difficulties in the learning process, students who had moderate performance, and students who had good performance. The interviews served multiple purposes: 1) to triangulate data with the survey and classroom observations, 2) to gain a deeper understanding of the beliefs held by the teacher and students regarding math ability, and 3) to explore how students perceived specific actions taken by the teacher. The interviews encompassed discussions and reflections on the experiences of both the teacher and students in relation to math, both within and outside the classroom.

The interview questions for the students in the case classes focused on their mindset, experiences, and perceptions of math (Sun, 2015). One of the objectives of the student interview was to gain insight into how students develop their theories of intelligence. Additionally, the interview aimed to enhance understanding of teacher practices, mindset, and behaviors from the student's perspective.

Data Analysis

By triangulating data (Carter et al., 2014; Flick, 2018) from the teacher and student beliefs, classroom observations, and interviews, the goal was to comprehensively understand the growth of mathematics instruction in the case study. It was intended to establish the connection between teacher and student mindsets in relation to the student's comprehension of linear function concepts. The authors identified teacher practices based on four belief constructs, which include teacher-reported practice items, teacher mindset, teacher expectations, and teacher beliefs about the nature of math, along with teacher-access views of math (Sun, 2015). Subsequently, the authors identified students' beliefs through four belief constructs: mindset, beliefs regarding the nature of mathematics, performance orientation, and identification with mathematics (Sun, 2015). Both teachers' and students' beliefs were measured using questionnaires. Furthermore, observations were conducted to provide an actual overview of the aforementioned teacher and students' beliefs. The observation results were also used to depict students' performance in mathematics learning. Moreover, interviews were conducted with several students from low, moderate, and high-performance groups to confirm the relationship between teacher and student mindsets and students' performance in understanding the linear function material.

RESULTS AND DISCUSSION

Teacher Belief

Teacher-Reported Practice Items

Teacher surveys completed at the beginning and end of the school year asked a number of questions related to self-reported teacher-reported practice items. There are two sets of measurement items in this case. The first set assessed how frequently teachers engage in learning practices, and the second set measured how often students engage in specific activities (Sun, 2015).

In the first set of items, teachers reported that they mostly group students based on their skills or ability levels (around 80% of the total class activities). Teachers also somewhat frequently (around 80% of the total activities) allow students to resubmit tests for remediation. Teachers also reported that they somewhat frequently (around 80% of the total activities) allow students to resubmit assignments, such as classwork and homework, for remediation. Furthermore, teachers occasionally discuss students' mistakes in front of the whole class. Lastly, teachers occasionally provide different assignments to different students based on their performance or abilities. In this measurement context, teachers occasionally engage in such practices in approximately 75% of the total class activities.

In the second set of items, teachers reported that approximately 2 or 3 times a month, they design learning experiences to provide opportunities for students to work in groups, engage in mathematical exploration or discovery, and participate in peer discussions. Teachers also reported that they provide opportunities for students to engage in discussions with their peers once a month or less frequently and that they explain students' reasoning abilities in written or oral forms 2 or 3 times a month. Additionally, teachers reported that students are asked to work on worksheets or math textbooks 2 to 4 times a week.

Based on the information provided, teachers with a more open-access perspective on which students can access more challenging tasks tend to refrain from reporting using ability grouping (Sun, 2015). Ability grouping or differentiating task difficulty based on student abilities leads to students developing a more robust fixed mindset (Yu et al., 2022).

Students with lower abilities tend to feel shame and believe that their math abilities cannot be improved, while students deemed to have good math abilities may feel they don't need to work as hard due to the special treatment they receive (Boaler et al., 2022). The teachers involved in this study reported frequently (around 80%) grouping and providing different tasks to students according to their abilities. However, they also reported frequently allowing students to resubmit tests and assignments for reassessment and discussing student mistakes when learning math in front of the class.

According to Sun (2015), teachers who frequently provide students with remediation opportunities tend to have a more open-access perspective. Furthermore, teachers with a more open-access perspective also believe that students should have access to complex tasks to be more likely to report errors in class discussions (Sun, 2015). Specifically, when students make mistakes and realize their errors, it can foster mental growth and be more beneficial for their cognitive development (Alvidrez et al., 2022; Boaler, 2022; Dweck, 2008). Based on this information, teachers are likely actively involved in the learning process with limited expectations for each student based on their abilities.

In the second set of items, teachers frequently provide students with opportunities to engage in the process of learning mathematics. This is evident from the frequent opportunities they provide for students to work in groups, engage in mathematical explorations, participate in peer discussions, and work on worksheets or math textbooks. Teachers also frequently explain students' reasoning abilities in written or oral forms. Learning opportunities are crucial in influencing students' learning (Schmidt et al., 2008) and have a direct relationship with motivation and enhancing students' academic functioning (Brewster & Miller, 2020) in mathematics learning.

Teacher Mindset

The statements used to measure teacher mindset are Statement 24 (Q24), Statement 30 (Q30), and Statement 32 (Q32). These three statements are closely related to the theory of entity intelligence, which assumes that mathematical ability is fixed (Sun, 2015). The following is a list of the three statements:

Q24 : There are limits to how much people can improve their basic math ability.
Q30 : You have a certain amount of math intelligence, and you can’t really do much to change it.
Q32 : Some students have a knack for mathematics and some just don't.

There is a scale of 6 response options related to these three statements: Strongly Agree, Agree, Somewhat Agree, Somewhat Disagree, Disagree, and Strongly Disagree. The teacher answered “strongly disagree” for Q24 and Q30, which means the teacher believes that mathematical intelligence is not fixed and can be developed. However, the teacher answered “agree” for Q32, indicating that the teacher agrees that some individuals have innate mathematical abilities while others do not. This suggests that the teacher believes that students’ mathematical abilities can be improved but also acknowledges that some people are born with inherent mathematical talent. In contrast, others may lack it, possibly referring to someone being a mathematical genius or having cognitive limitations. Overall, the teacher holds a growth mindset regarding students' ability to develop their mathematical skills (Boaler, 2022; Sun, 2015).

Teacher Expectations

There are three statements used to measure teacher expectations, namely statement 19 (Q19), statement 25 (Q25), and statement 28 (Q28). The following is a list of these statements:

Q19 : In math class there will always be some students who simply won't "get it."

Q25 : Some students are not going to make a lot of progress this year, no matter what I do.

Q28 : In my class(es), students who start the year low performing tend to stay relatively low performing at the end of the year.

These three statements are related to the teacher's beliefs about whether all students can succeed (Sun, 2015). This pertains to students' progress, understanding, and performance. The response scale for these statements is also similar to the previous statements used to measure teacher mindset.

In Q19, the teacher answered, "Somewhat disagree." This means that the teacher has some doubts when making decisions but ultimately leans towards the belief that all students can understand mathematics. Furthermore, the teacher strongly disagrees with Q25 and Q28. This indicates that the teacher firmly believes that every student can make progress in learning mathematics and also believes that students' initial performance at the beginning of the year or semester is not the primary indicator of their mathematical performance and ability to achieve better understanding by the end of the year or semester. This information demonstrates that the teacher has high expectations (Sun, 2015) for their students in learning mathematics and believes that every student can develop and succeed.

Teacher Beliefs about the Nature of Math

These beliefs are measured using four statements: Statement 21 (Q21), Statement 23 (Q23), Statement 26 (Q26), and Statement 27 (Q27). These four statement items are designed to reflect the teacher's beliefs about mathematics's one-dimensional and multidimensional views (Boaler, 2022; Sun, 2015). The one-dimensional view of mathematics represents a more procedural or rule-based perspective, while the multidimensional view of mathematics encompasses conceptual understanding, procedural fluency, understanding of meaning, and problem-solving strategies (Kilpatrick et al., 2001; Sun, 2015). The following is a list of the four statements:

Q21 : Mathematics involves mostly facts and procedures that have to be learned.

Q23 : There is usually only one way to solve a math problem.

Q26 : In mathematics, answers are either right or wrong.

Q27 : Discussing students' errors with the class is a good strategy for enhancing students' understanding.

The four statements were also measured using the previously provided 6-point response options. The teacher strongly agrees with Q21, indicating that they believe mathematics is more than just a collection of facts and procedures that need to be learned. Furthermore, the teacher strongly disagrees with the statement that suggests there is only one way to solve mathematical problems (Q23). This suggests that the teacher tends to believe that mathematics involves multiple solutions, even though they also believe it involves facts and procedures. Additionally, the teacher agrees that mathematics involves right or wrong answers (Q26) and also agrees with Q27, which relates to discussing mistakes to enhance students' understanding. There needs to be more consistency in the teacher's perspective on whether mathematics is viewed from a one-dimensional or multidimensional perspective, and this uncertainty in beliefs may impact how students perceive mathematics.

Teacher Access Views of Math

There is a strong relationship between teachers' beliefs about students' abilities and students' beliefs and performance (Elizar & Khairunnisak, 2022). Many teachers believe that each student should have different access based on their abilities (Zohar et al., 2001). Teachers' beliefs regarding teacher access views of mathematics are measured using two statement items, namely statement 34 (Q34) and statement 37 (Q37), on a five-point scale. This measurement aims to understand teachers' responses regarding whether they differentiate access between high-achieving and low-achieving students. In this context, teachers with a closed mathematics access view tend to group or separate students based on their achievements (Sun, 2015). Here are the two statement items used:

Q34 : How important is it for students to acquire basic math skills before engaging in complex conceptual math problems?

Q37 : When learning math, how important is it that students are placed into math classes according to their math achievement (ability grouping)?

The teacher responded with "very important" for both of the statements above. According to Sun (2015), this indicates that the teacher tends to have a closed belief towards teacher access views of mathematics. In other words, the teacher believes that students should be separated based on their abilities when solving mathematical problems during the learning process.

Teacher Belief Summary

The teacher reports that they have provided opportunities for students to be involved in the learning process, but they also tend to have limited expectations for students in learning mathematics. The teacher also believes that students have different foundational mathematical abilities, meaning that some can learn mathematics well while others cannot. However, on the positive side, the teacher has a belief that students' mathematical abilities can still develop through hard work. This shows that the teacher believes that hard work can improve mathematical abilities, although there may be limits to the abilities that can be achieved.

The teacher also tends to view mathematics as a set of rules that students must learn, even though they believe that there is more than one way to solve mathematical problems. The teacher also believes that foundational mathematical abilities are crucial for students to achieve good performance in learning mathematics, and they also believe that the best way to teach mathematics is by providing different access to students based on their abilities. This reinforces the previous statement that the teacher believes that each student has limitations in achieving mathematical understanding.

Students Belief

Student Mindset

The measurement of student mindset involved three statements that were assessed using a six-point agree/disagree scale. These statements aimed to evaluate students' beliefs regarding their mathematical abilities. The three statements used to measure the student mindset construct are Q5, Q9, and Q11.

Q5 : You have a certain amount of math intelligence, and you can't really do much to change it.

Q9 : There are limits to how much people can improve their basic math ability.

Q11 : Some kids can never do well in math, even if they try hard.

Figure 3 illustrates the response results of a group of students to the three statements. It shows that, on average, a group of students agree that there are limitations to an individual's ability to learn and improve their mathematical skills, even with hard work. This indicates that students have a fixed mindset in this regard (Sun, 2015). However, the belief that anyone can achieve any level of mathematical proficiency through hard work can foster a growth mindset, which is an indicator of mathematical achievement and a predictor of future success (Boaler, 2022; Huang et al., 2019; Hwang et al., 2019; Sun, 2018).

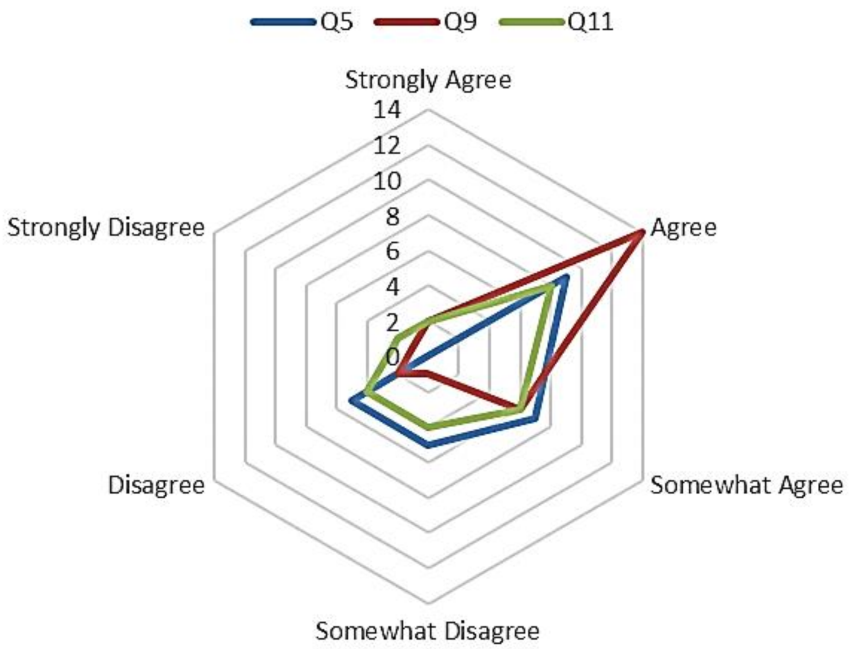

Figure 3. Students Mindset

Student Beliefs about the Nature of Math

The fundamental nature of mathematics is closely related to students' self-confidence, anxiety, interest, and perspectives on mathematics (Hurst & Cordes, 2017; Kloosterman, 2002). Here are the statement items used to measure students' beliefs about the nature of mathematics:

Q4 : Mathematics involves mostly facts and procedures that have to be learned.
Q6 : People who really understand math will have a solution quickly.
Q8 : In math, answers are either right or wrong.

There are six items to measure student responses to the statements above. Figure 4 is the response of a number of students' beliefs related to the nature of math. It shows that a number of students, the majority of them, agree that mathematics primarily involves facts and procedures (Q4) and believe that someone who truly understands mathematics will quickly find a solution (Q6). Additionally, more than 50% of students tend to believe that in mathematics, answers involve only right or wrong (Q8). These findings align with the beliefs held by teachers, indicating a potential relationship between students' beliefs and teachers' beliefs regarding their perspectives on the nature of math.

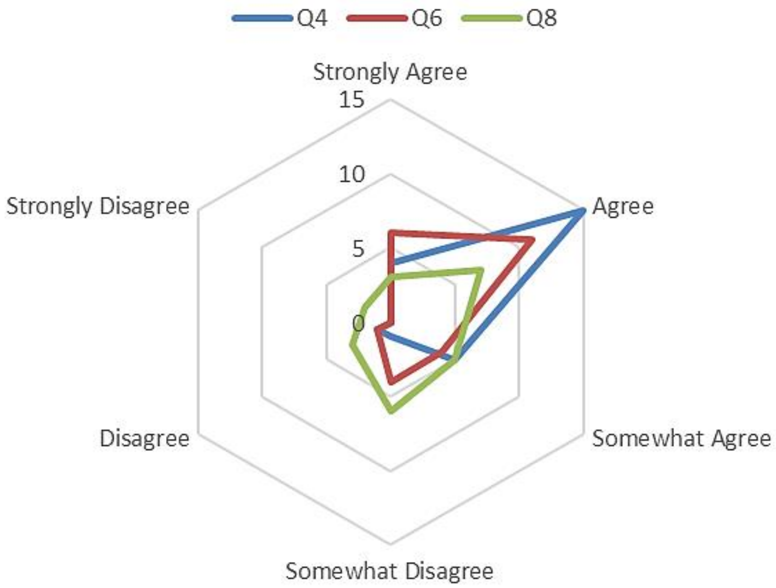

Figure 4. Student Beliefs About the Nature of Math

Student Mastery (vs. Performance) Orientation

Some studies have shown that students' mastery orientation has an influence on their interest, motivation, and academic achievement in mathematics (Furner & Gonzalez-DeHass, 2011; Owusu et al., 2022). The construct consists of four statements that capture students' perceptions regarding performance-related behaviors, including the willingness to make mistakes and the desire to obtain correct answers. Here are the specifics of the four statement items:

Q15 : In math, how important is it to avoid making mistakes?
Q16 : How important is it that you to do better than other students in your math class?
Q17 : In math class, how important is it to get the right answer?
Q18 : How important is it that you do well in math?

The responses of a group of students to the statements mentioned above are displayed in Figure 5. It shows that most students believe that their basic abilities are indicators of their mathematical performance. In other words, students consider it highly important to have a strong foundation in mathematics to learn mathematics, especially at an advanced level. Indirectly, students also believe that making mistakes is unacceptable in learning mathematics, as indicated by their "extremely important" response to statement Q17.

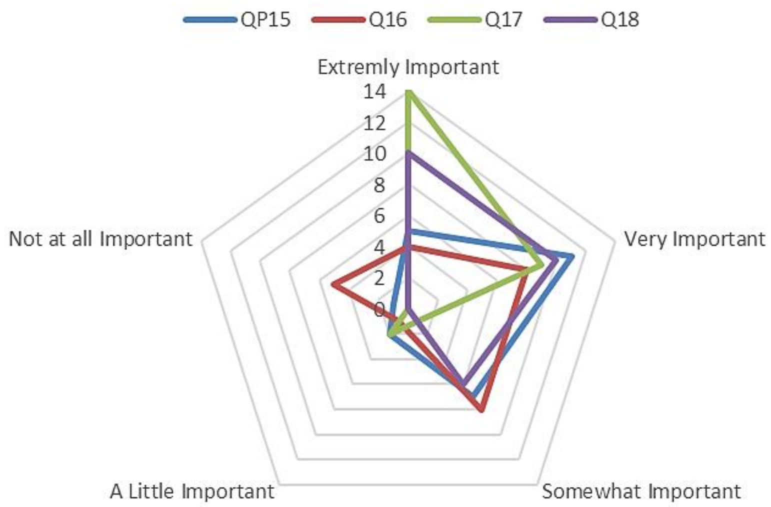

Figure 5. Student Mastery (vs. Performance) Orientation

Student Identification with Math

Four items were used to measure student identification with math. There are four statements to measure student identification with math. A higher mean scale score for this construct would indicate more of a positive identification with mathematics. The following is the statement:

Q10 : I see myself as a “math person”.
Q12 : How much do you like math?
Q13 : Math is___________ for me.
Q14 : I am____________ at math.

Figure 6 is the response of a number of students to students’ identification with mathematics. It shows that students responded similarly to statements 13 and 14 regarding their assessment of mathematics. The majority of students agree that mathematics is neither good nor bad for them, and they also feel neutral about mathematics. This suggests that students tend to give a neutral assessment in this regard. Furthermore, some students disagree with the statement that they feel like math person, but a considerable number of students do feel like math people. This is reinforced by statement 12, which indicates that the majority of students have a neutral attitude toward whether they like mathematics or not.

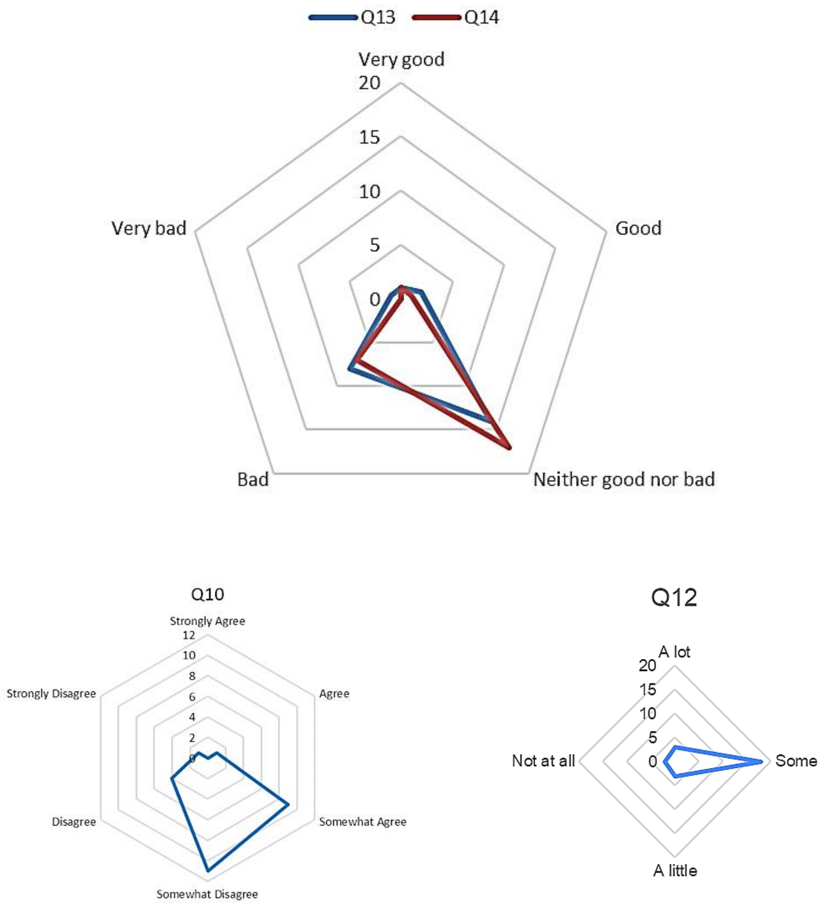

Figure 6. Student Identification with Math

Students Belief Summary

Most students tend to have fixed beliefs about mathematics, as assessed by their mindset, beliefs about the nature of math, and their orientation towards mastery and performance. Students also need help deciding whether they identify as a math person or whether they like or dislike mathematics. This conclusion aligns with the previously discussed teacher beliefs, although in their reports, teachers often provide learning opportunities for students in mathematics classrooms.

Classroom Observation

The learning took place over two sessions during the process, and students were provided with worksheets related to linear functions. The worksheets given to the students were sourced from the website www.youcube.org, which is managed by Joe Boaler and his team, aiming to assist teachers worldwide in implementing the learning process with a growth mindset interaction approach to accommodate multidimensional learning. Figure 7 represents an example of the worksheet used during the classroom learning process.

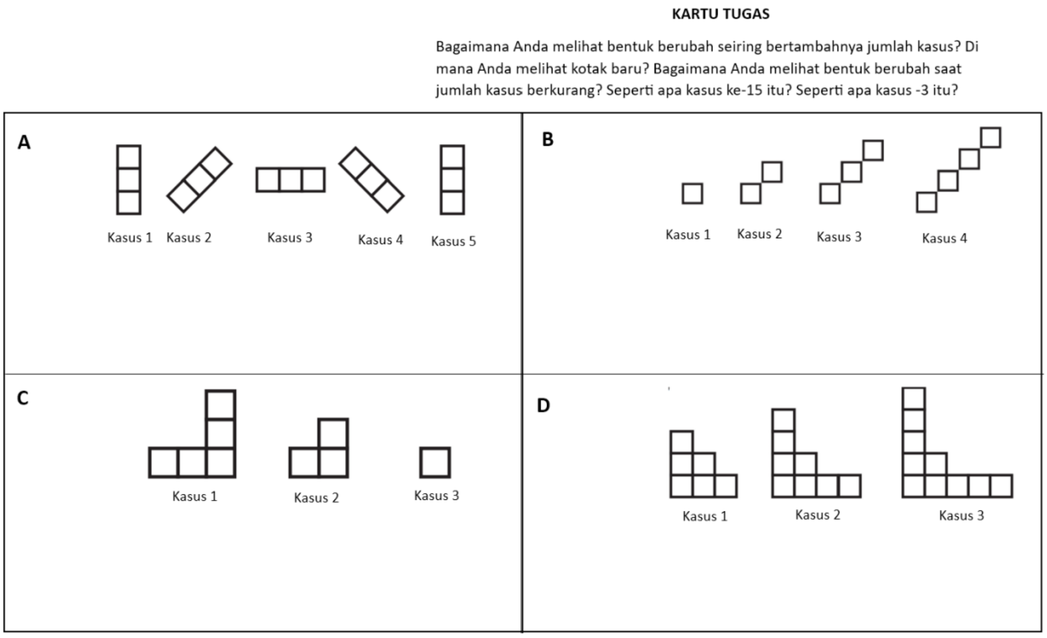

Figure 7. Worksheet of Concept Linear Function

The following is the translation of the instructions that students should follow regarding the worksheet mentioned above:

1. How do you see the shapes change as the case number increases?
2. Where do you see the new squares?
3. How do you see the shapes change as the case number decreases?
4. What would the 15th case look like?
5. What would the -3 case look like?

The data sources used during the classroom observation process included video recordings, photos, and various notes taken throughout the learning activities (Guimarães & Lima, 2021). The entire teaching process was not recorded, but recordings were made several times during specific parts deemed essential to pay attention to. Photographs were taken frequently, especially when students engaged in different activities in the classroom. Besides utilizing audio and video equipment to record the interactions during the classes, I was personally present to take comprehensive field notes. These field notes were essential for indexing specific events that occurred in the classroom and proved valuable for ongoing analysis.

Learning Process

In-class learning is conducted to assess students' performance in multidimensional mathematical concepts. In its implementation, students were divided into six groups, each consisting of 5-6 students, considering the absence of some students. The grouping was done randomly to avoid unfairness for students with fewer social connections in the class. Subsequently, students were given task cards, as shown in Figure 7, related to the topic of linear functions.

The discussion process began with students recognizing and extending visual patterns through task cards. In this process, students were encouraged to spend time without relying on specific numbers or calculating the number of squares in each case. The goal is to work visually, thinking about how the pattern grows and where the extra boxes are seen. The formal mathematical objective of these task cards is to provide students with an understanding of the concept of continuous functions based on the function's domain in linear functions. Students were then given the opportunity to write down their work on cardboard for further discussion in the classroom. Figure 8 is a photographic documentation of the exploratory stage of the learning process.

Figure 8. Material Exploration

Algebraic Thinking Ability

At the beginning of the discussion process, some groups needed clarification about the given task. Students needed guidance about what to do to complete the task, resulting in many questions being asked before they started working. This indicated the need for additional didactic assistance. Additionally, some groups still needed help understanding the pattern. One group even approached the task by constructing a new form from multiple existing patterns. These difficulties indicate that students had problems with algebraic thinking (Kusumaningsih & Herman, 2018; Radford, 2018; Sibgatullin et al., 2022) despite exposure to the material.

Creativity and Confidence

Students also faced challenges with creativity and self-confidence. When students were informed that they could continue the pattern upwards or downwards according to their creativity and how they perceived the pattern, most groups often asked for confirmation whether their answers were correct or not when attempting to continue the pattern. This indicates that students need help to initiate the application of an idea in mathematical learning and demonstrates their low level of creativity in mathematics (Haavold & Sriraman, 2022; Mann, 2006).

Interest and Motivation

Some students tried their best, even though they faced difficulties in solving problems within the given time. This is certainly a positive note. However, there were also groups where almost all members needed more motivation, even to complete a single part of the given task. Figure 9 shows the work results from two groups with low motivation.

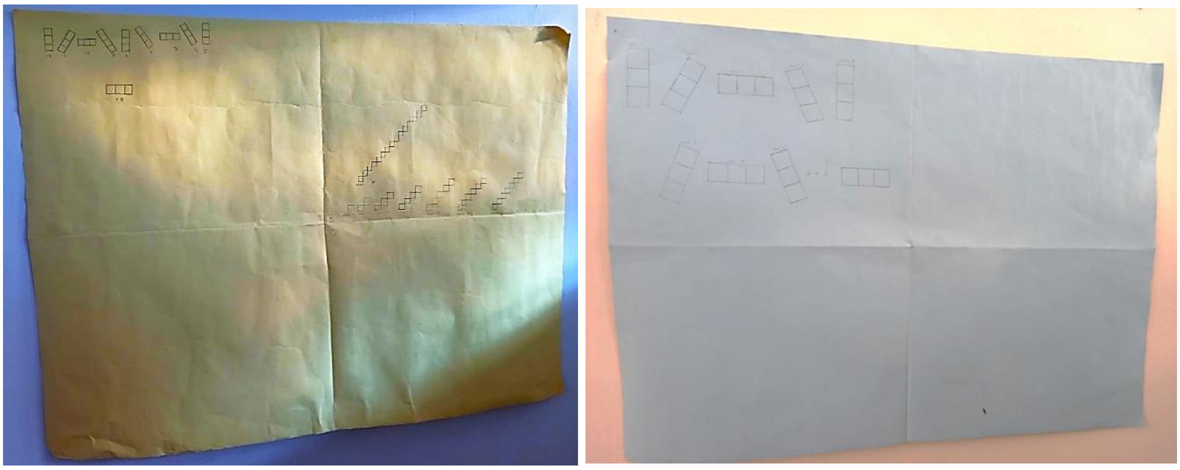

Figure 9. Student Work Results with Low Motivation

Figure 9 shows that both groups only worked on one or two problems, and it appears that they still need to complete them. Confirmation was done upon the members of those groups, and they mentioned that they did not understand even after being told several times. Furthermore, the majority of those groups seemed uninterested in the given task, which also affected the other group members. The cause of this could be attributed to their beliefs about their basic abilities, resulting in a fixed mindset (Boaler, 2022; Sun, 2015). They believe that whatever they do will not improve their mathematical abilities. One person from each of the two groups was interviewed to gain deeper insights, and the results are discussed in the interview findings section.

Enthusiasm and Mindset

There are also groups whose members demonstrated good perseverance, as reflected in the efforts made by the other four groups. Some students in these four groups represent students who believe that one's mathematical ability can be improved through effort and hard work (Boaler, 2022; Dweck, 2006; Samuel et al., 2022). However, it is interesting that there is still a fixed mindset in their perception of the nature of math within their perseverance. Students repeatedly sought confirmation of whether their work was right or wrong (Sun, 2015; Szczygieł & Pieronkiewicz, 2022), reinforcing the student questionnaire's findings regarding their beliefs about the nature of math. As a result, the perseverance shown by these students is similar to when students try to solve numerous procedural mathematical problems. This behavior is a form of imitative reasoning (Herman, 2018) deeply ingrained in students in Indonesia.

Figure 10 shows the results of group work with enthusiastic members. Both groups shown in Figure 10 managed to complete all the given tasks but only worked on some of the questions. In fact, the groups in Figure 9 could only partially complete question number 1. Based on observations, these groups needed more time to complete their tasks thoroughly and successfully.

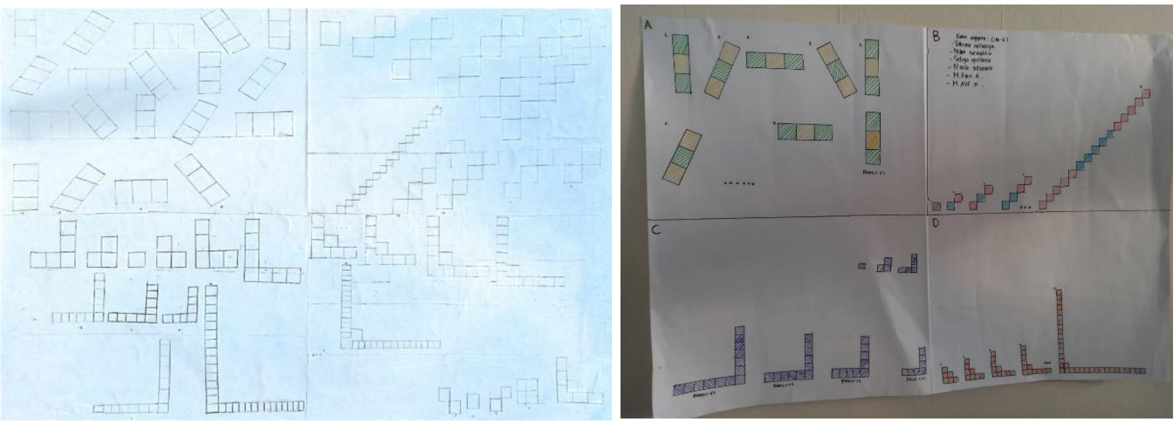

Figure 10. Results of Student Work with Enthusiasm

Reflection

On the lesson plan, there should have been a reflection at the end of the learning process to assess understanding of continuous functions based on the specified domain. This reflection was intended to be conducted through a question-and-answer session among groups in the classroom after each group completed their respective posters. However, in practice, the reflection activity could not be carried out because students still needed help in recognizing linear functions through visual patterns. Therefore, it can be concluded that the student's performance still needs to improve in understanding the concept of linear functions. This could be attributed to the factors mentioned earlier and may be related to the mindset of both the teacher and the students, as indicated by the questionnaire results.

Observation Summary

The observation results indicate that students' performance in recognizing and understanding the basic concept of linear functions through pattern recognition with visual shapes falls into the low category. The low performance can be attributed to several factors, including the inability to recognize visual patterns. In other words, students have low algebraic thinking skills (Radford, 2018; Sibgatullin et al., 2022); another factor is low confidence and creativity in students. In addition, some students also have low motivation due to their belief in the fixed mindset of mathematical ability (Boaler, 2022; Sun, 2015, 2018); the last factor is related to students' mindset, where students believe that mathematics consists of a set of rules and procedures related to right and wrong answers. A positive aspect noted during the observation is the students' perseverance. Some students demonstrated good perseverance in tasks based on visual patterns.

Interview Results

There were two students selected as participants for the interview. The first student was chosen from the group with low performance, while the second student was selected from the group with high perseverance. The purpose of the interview was to validate the results obtained from the teacher and student questionnaires, as well as the classroom observation.

Student's Mindset

The following is a snippet of the interview transcript related to the student's mindset. Student names are pseudonymized with X for the first student and Y for the second student.

First student,
Interviewer: "... X according to X, what do we need to be good at math?"
Student: "Study!"
Interviewer: "What is the specific study like?"
Student: "Studying is like... if I study it's like at four in the morning right, so I get in like that, so it's not like yesterday, so I like studying at four in the morning when I want to take a test or there are students."
Interviewer: "Math?"
Student: "Yes."
Interviewer: "What about mathematics specifically? Learning is the same for other students, isn't it, studying too. How about math?"
Student: "Practice diligently!"
Interviewer: "Are there any more? How is it different from other lessons? It's like math, you have to do this."
Student: "Mathematics must know the formula first then understand."
Interviewer: "So how do you do it, to be smart, math? Haha."
Student: "Yes, let me know the formula!"
Interviewer: "Memorize the formula, that's it?"
….
Student: "It's easy if you already know the formula."

Second student,
Interviewer: "… According to Y, what do you think is needed for us to be good at math? Just in Y's opinion, … Y's thought is that if you want Y to do the math, what do you need, what do you need?"
Student: "You have to study... at home quietly, if you have free time, we study like that. Remembering... leafing through a package like that."
….
Interviewer: "Well, for example, talk about students in your class who are smart, right? So, what did this smart student do, so that he became good at math? What do you think he did to make him so smart?"
Student: "Yes, it's like before, study in class when there is free time, leaf through textbooks while chatting with friends like to leaf through books together…. makeup questions with friends like that, ask them to answer things like this… like that."

Both students believe that to be good at mathematics, one needs to study. Both students elaborated on the details of studying, which included practicing regularly and memorizing formulas. Student X even emphatically stated that mathematics is easy if you memorize the formulas. The information from the interview excerpt aligns with the results of the student questionnaire, indicating that students have a fixed mindset regarding their perception of mathematics (Boaler, 2022; Sun, 2015). This fixed mindset is also a contributing factor to students' low performance in recognizing and understanding the concept of linear functions during the learning process, as student mindset is closely related to self-beliefs and motivation and then influences the mathematics learning process (Huang et al., 2019; Hwang et al., 2019; Negara et al., 2021; Sun, 2018). Students believe that mathematics is nothing more than facts and procedures that must be memorized.

Experiences

The interview excerpts below are related to students' perspectives on basic abilities orientated in mathematics and their relationship to student performance in mathematics. In addition, this section also confirms the teacher's report in instilling a growth mindset in the classroom. The following is a transcript of the interview with the first student.

Interviewer: "…. So, if you see a friend who is good at math? Eeee, how is he studying?"

…

Student: "Yes, if I ask him, he often studies, like that, right? He's also a nerd, he's here too, isn't there a lot of them? He took part in the Olympics, so yeah, you know maybe…"

…

Interviewer: "According to X, are there people who are inherently good at math?"
Student: "There are! I said there is, rich. The problem is I have a friend, who never studies, but once he wants to do that, he knows everything."

…

Interviewer: "According to X, if the teacher is in the class, do you believe that or not, that indeed everyone is different, there is potential."
Student: "Different, yes!"
Interviewer: "So in the process in class, does the teacher treat the same or not?"
Student: "Same, the teacher also understands, how come this one is like this, that one is like that."

…

Interviewer: For example, in mathematics, you do something wrong. What is the teacher's response?
Student: Correct it again, if for example the teacher still can't, change the person again, until the answer is correct.

The transcript of the interview with the first student indicates that the student believes that someone's ability in mathematics is fixed. This implies that the student believes little can be done to improve their mathematical ability, no matter how much effort they put into it. This is related to the teacher's beliefs and practices in the classroom. The student reports that the teacher indirectly treats students differently based on their abilities. It means that the teacher has fixed student expectations (Boaler, 2022; Kroeper et al., 2022; Sun, 2015). Additionally, whether the teacher views mistakes as valuable or not needs to be clarified. This is further supported by the second student's report in the following interview quote:

Interviewer: "Then if for example, someone makes a mistake then what about the teacher? For example, when doing the problem wrong, how do you usually respond?"
Student: "The best thing is to fix it again with my friends while chatting. So, let's help friends who haven't yet, like the formula, just like that."

The first student reports that if all students whether their answers are correct or incorrect, they will move forward together, and for students who answer incorrectly, their classmates will help them write the correct answers. Additionally, the second student reports that for students who answer incorrectly, the teacher immediately instructs other students to correct their mistakes without presenting them in front of the class first.

Perceptions of Math

The interview questions in this session aim to confirm the students' perceptions of mathematics. Previously, the survey results indicated that students tended to be neutral when identifying themselves in relation to mathematics. The following are interview excerpts from the first and second students regarding their perceptions of math.

First student,

> ***Interviewer***: "This is about a view of mathematics, does X actually like mathematics?"
> ***Student***: "Love it! As long as you already know the formula, X likes it. But it's a headache, sir."
> ***Interviewer***: "He he. What's the headache?"
> Student: "Always working! Sometimes I like to knock, that's the formula."

Second student,

> ***Interviewer***: "Does Y like or dislike math actually?"
> ***Student***: "I really like it, but it's a headache… he he. I can't... he he."

Based on the interview excerpts, both students expressed that they like mathematics, but they find it difficult and struggle with memorizing formulas, making mathematics confusing for them. The students' liking for mathematics, combined with their difficulty in learning it, results from their belief that mathematics is essential (Hagan et al., 2020). This information aligns with the neutral responses in the survey. The interview quotes demonstrate that the students enjoy mathematics but need help understanding procedural and memorization-based aspects of it. According to studies, students' perception of mathematics is one of the affective factors contributing to their performance in solving mathematical problems (Öztürk et al., 2020; Schoenfeld, 1989; Sun, 2018). This reflects their mathematical experiences so far and confirms the teacher's belief in the same matter.

The students also expressed the same concern when asked for their suggestions on making the mathematics learning process more engaging. The first student suggested making the learning process more exciting and hoped that mathematics could be taught like a game, as indicated in the following interview quote:

Interviewer: So, according to X, is there anything that needs to be changed (related to learning mathematics)? Let the students like it.
Student: "...the more interesting, the lessons are even more interesting."
Interviewer: "Interesting, like how?"
Student: "It's interesting to make it into a game or something like that."

On the other hand, the second student suggested reducing the number of assigned tasks and complained about the abundance of formulas, as indicated in the following interview quote:

Interviewer: "... According to Y, how do you get those students, or at least Y, to like mathematics?"
Student: "... The assignments shouldn't be too difficult, or the formulas shouldn't be too many; yeah, it's a headache."

Once again, the quote indicates that the mindset and practices of the teacher in the learning process significantly influence the mindset and performance of students in learning mathematics.

CONCLUSION

This study found a significant relationship between teachers' and students' mindsets in relation to students' performance through the practices of mathematics teaching in the classroom. Teachers and students have closed beliefs about the nature of math, believing that it is a set of facts and procedures. Teachers also have a closed belief in the access view of math and mastery orientation. This means that teachers and students both believe that there are limitations in developing mathematical abilities, one of which is basic mathematical abilities. Therefore, the teacher believes that students should be separated according to their abilities when solving math problems in the learning process. The students' fixed mindset also manifested in their performance in learning linear functions in the classroom. The students held fixed beliefs about their basic abilities and their perception of mathematics, which led to a lack of motivation and self-confidence, resulting in difficulties in understanding mathematical concepts effectively, and also experienced problems in algebra thinking. A suggestion for future research is to develop an instructional design using didactic art or a teaching design that integrates artistic approaches to mathematics content based on the theory of mathematical mindset to address the issues of fixed mindsets in both teachers and students and the instructional practices identified in this study.

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