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GROWTH MINDSET, PERSPECTIVE-TAKING, AND ACHIEVEMENT: THE MEDIATING ROLE OF MATH SELF-EFFICACY

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Abstract

Mathematics plays an important role for students academically and at the workplace. Psychological factors such as growth mindset and perspective-taking contribute to mathematics achievement. To date, however, their cumulative effect on math achievement has not been widely examined, warranting investigations into their combined influence on students' learning of mathematics. This study aims to explore the relationship between a growth mindset and perspective-taking with mathematics achievement among high school students. Additionally, this research investigates the mediating role of mathematics self-efficacy in this relationship. Secondary data analysis was conducted using the PISA 2022 database, with high school students from Indonesia as subjects. The Structural Equation Modeling (SEM) method was employed to analyze the collected data. Statistical analysis results indicate that the proposed measurement model and research instruments are valid and reliable. The study finds that a growth mindset is positively and significantly related to mathematics achievement ($\beta = 0.225^{***}$), as is perspective-taking ($\beta = 0.228^{***}$). Moreover, the study confirms that mathematics self-efficacy mediates these relationships. Practical implications for high school education are discussed in this research.

Keywords: Growth mindset; Math achievement; Math self-efficacy; Perspective-taking; PISA

1. Introduction

Mathematics is one of the foundational skills that determine the success of high school students in professional and academic perspectives. It helps students in acquiring critical thinking and prepares them for a career that requires quantitative reasoning. Recent research underlined the importance of psychological factors, such as growth mindset and perspective-taking, in relation to students' achievement. A growth mindset has been described as the belief that abilities can be developed through dedication and hard work and is associated with increases in motivation and resilience within learning contexts (Dweck, 2008; Burnette et al., 2013). The last couple of years have seen inconsistent findings on whether a growth mindset is linked with math learning achievements (Burnette et al., 2013; Yeager & Dweck, 2020). Whereas some researchers report a positive relation between growth mindset and math achievement (Blackwell et al., 2007), other studies point to no relation or even a negative one between those two variables (Bahník & Vranka, 2017; Li & Bates,

2019; Yeager & Dweck, 2020). Recent research established an indirect relationship between those two via intrinsic motivation (Dong et al., 2023).

Perspective-taking is the knowledge of others' points of view and might help improve interactions in social settings and learning processes. Such a cognitive process could have significant implications for students' performances in academics, most especially in mathematics, where collaboration in problem-solving often is a must. Previous research has located perspective-taking as related to the cognitive processes that underlie mathematical reasoning. Therefore, it is expected that students who can envision perspectives from multiple places execute especially well on tasks that require spatial reasoning (van den Heuvel-Panhuizen et al., 2015).

Although all three of these concepts have been considered separately, no attempt has yet been widely made to determine the impact of combining them on academic achievement, particularly in mathematics. A situation like this invites the researcher to further explore the role of a growth mindset and perspective-taking in students' mathematical learning. The present study will focus on the relation of growth mindset, perspective-taking, and math achievement among high school students in Indonesia, with special emphasis given to the mediating effect of mathematics self-efficacy. Mathematics self-efficacy is defined as one's belief in his or her capability to perform tasks involving mathematics. According to Bandura (1997), mathematics self-efficacy has very important effects on academic performances. Specifically, the study uses data from the PISA 2022 assessment in its search for answers on how those psychological constructs combine and interact in enhancing or impairing students' performance in mathematics.

Literature Review

Growth mindset and mathematics achievement

A growth mindset is based on the view that ability or intelligence is not inborn but rather developed. Such a mindset then leads students to embrace challenges, surmount obstacles, and view failure as an opportunity to learn. It's quite important to install a growth mindset in mathematics education, since this subject is considered complex and this always tends to lead to stressful levels amongst learners.

A comprehensive literature review since 2007 showed that growth mindset was a key predictor of math achievement for high school students in countries with various tracks. This study has shown that students with growth mindsets are more likely to set self-improvement goals, seek feedback, and attribute failures to controllable factors, thus achieving higher academic results later on (Stohlmann & Yang, 2024). Other evidence shows that growth mindset interventions can encourage students to engage in and perform well in mathematics classes (Van Hoeve et al., 2023). The authors go ahead to develop the hypothesis below from this description:

H1: Growth mindset positively and directly relate to mathematics achievement.

Perpective-taking and mathematics achievement

Perspective-taking refers to understanding another's point of view; it has been realized as one skill of great importance in terms of fostering empathy, collaboration, and problem-solving abilities (Gehlbach et al., 2012). This ability is anchored on social cognitive theory, which postulates that individuals learn behaviors and skills through observation and interaction within their environments (Bandura, 1986).

Literature has shown that perspective-taking generally does not have an honest-to-goodness relationship. However, it has consequences for perspective-taking in terms of generosity, moral condemnation, empathy, and group dynamics (Barth & Stürmer, 2016; Lucas et al., 2016; Sassenrath et al., 2016; Oztop et al., 2018).

On the other hand, emotional intelligence—the ability of recognition of one's own and others' emotions, empathy, motivation, and self-control—has been mentioned as a factor that can improve students' academic performance (Mansir & Karim, 2020; Ngui & Lay, 2020; Pekaar et al., 2020; Wood, 2020; Chinyere & Afeez, 2022). From this description, note that perspective-taking is associated with math achievement. Hence, the authors then formulate the following hypothesis:

H2: Perspective-taking positively and directly relate to mathematics achievement.

The role of mathematics self-efficacy

Mathematics self-efficacy refers to an individual's belief in their ability to successfully perform mathematical tasks. Previous research has shown that mathematics self-efficacy is a strong predictor of math achievement, and often serves as a mediator in various educational contexts. In relation to a growth mindset, one study found that a growth mindset indirectly predicts math achievement among college students through the mediating effects of self-efficacy and reasoning ability (He et al., 2024). For elementary school students, a mindset about intelligence positively influences children's math achievement, with mathematics self-efficacy and beliefs about failure fully mediating this relationship (Su et al., 2021). Additionally, parents' beliefs about failure positively affect children's math achievement through the mediating effects of children's responses to failure, mathematics self-efficacy, beliefs about failure, and a growth mindset (Su & He, 2024). A growth mindset may also indirectly influence math achievement through intrinsic motivation, failure attribution, and mathematics self-efficacy among high school students (Dong et al., 2023). From this description, it is apparent that self-efficacy is one of the crucial mediators in the relationship between a growth mindset and math achievement across different education levels.

Perspective-taking can have positive or negative consequences based on the context and the intentions attributed to others (Lucas et al., 2016). It can also go awry when people feel threatened by perceived actions during perspective-taking (Sassenrath et al., 2016). On the other hand, perspective-taking boosts emotional recognition and empathy, which would otherwise be vital elements in understanding the perspective of others (Erle & Funk, 2022). Although it was found that anger reduces the ability for perspective-taking (Yip & Schweitzer, 2019), closeness in interpersonal relationships can positively influence group creativity but, combined with perspective-taking, has negative effects (Oztop et al., 2018). From this description, it is easy to infer that perspective-taking plays a complex role in interpersonal interactions and emotional understanding, which may indirectly influence self-efficacy in different domains, including mathematics. Based on this explanation, the authors then formulate the following hypothesis:

H3: Mathematics self-efficacy positively and directly relate to mathematics achievement.

H4: Mathematics self-efficacy mediates the relationship between growth mindset and mathematics achievement.

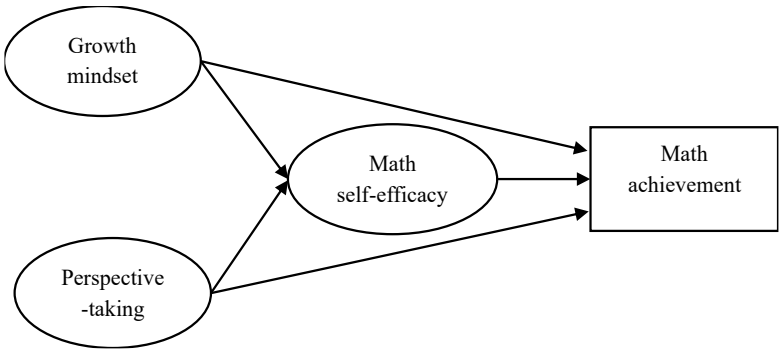

Figure 1 Research framework

H5: Mathematics self-efficacy mediates the relationship between perspective-taking and mathematics achievement.

Research Framework

Based on the literature review and the formulated hypotheses, a research framework was developed to test the relationships among the variables in this study, as shown in Figure 1.

2. Methods

2.1. Participants

The data for this study was obtained from the 2022 Program for International Student Assessment (PISA 2022) dataset, where the target population of PISA is 15-year-old students from participating countries. This study focuses on high school students from Indonesia. Data examination was conducted prior to analysis to identify any missing or invalid data. To address missing or invalid data, the study performed imputation using the random forest imputation method (Shah et al., 2014). After imputation, a total of 6,528 students were selected as participants in this study, with a nearly balanced gender ratio of 48.0% male and 52.0% female. The majority of students came from schools located in rural areas, totaling 4,708 students (72.1%), while the remaining 1,820 students (27.9%) attended schools in urban areas. In terms of school type, most participants attended public schools, comprising 62.8%, while 37.2% attended private schools. Based on the school program, 53.7% of students were from general programs, while 46.3% were from vocational programs. Detailed demographic data of the participants are presented in Table 1.

2.2. Variables

2.2.1. Independent variables

The independent variables in this study are growth mindset and perspective-taking. The growth mindset was measured using a 4-point Likert scale related to students' agreement with statements about growth mindset (e.g., “Your intelligence is something about you that you cannot change very much”: PISA code ST263Q02JA). The Cronbach's alpha value for the growth mindset scale is 0.742, indicating good reliability. Furthermore, perspective-taking was measured using a 5-point Likert scale related to students' agreement with statements about perspective-taking (e.g., “I try to consider everybody's perspective before I take a position”: PISA code

ST303Q01JA). The Cronbach's alpha value for the perspective-taking scale is 0.737, also indicating good reliability.

2.2.2. Dependent variables

The dependent variable in this study is students' math performance. The Item Response Theory (IRT) a model was used to estimate the probability distribution of each student's performance on the mathematics' subject test. In PISA 2022, there are 10 replicates to form 10 plausible values (PISA codes PV1MATH – PV10MATH). This study calculates the average of 10 plausible values to establish the students' math performance score.

2.2.3. Mediating variable

The mediating variable in this study is students' mathematics self-efficacy, which was measured using a 4-point Likert scale related to students' assessments of how confident they feel in completing various formal and applied mathematical tasks (e.g., "How confident are you in math tasks: Understanding scientific tables presented in an article": PISA code ST290Q04WA). The Cronbach's alpha value for the mathematics self-efficacy scale is 0.925, indicating excellent reliability.

2.2.4. Control variables

The control variables in this study include family background, teacher quality, and gender. It is well-known that family background, such as family socioeconomic status, culture, and social status, influences student achievement (Zhao & Bodovski, 2020). For this study, it is necessary to control for the factors of students' family background, which are measured using the Economic, Social, and Cultural Status (ESCS) from PISA data. In addition, students' performances are also dependent on teacher quality (Harris & Sass, 2011). The percentage of teachers with at least a master's degree is the measure of teacher quality for this study. Finally, gender is also used as a control variable as previous studies have identified varying impacts of gender differences on knowledge, performance, and skills of the students (Salanova et al., 2010). For this reason, gender was also added to the list of control variables in this study.

3. Results and Discussion

3.1. Measurement model analysis

Evaluation of the reflective measurement model shows a high correlation of all reflective indicators with their respective constructs. The factor loadings of each item in this study are above the threshold 0.708, hence the constructs explain more than 50 percent of the variance of the indicators, thereby providing acceptable item

Table 1 Participant demographics

		N (%)
Gender	Male	3,131 (48.0)
	Female	3,397 (52.0)
School location	Urban	1,820 (27.9)
	Rural	4,708 (72.1)
School type	Public	4,100 (62.8)
	Private	2,428 (32.2)
School program	General	3,506 (53.7)
	Vocational	3,022 (46.3)

Table 2 Descriptive statistics and measurement model

Construct	Items	Mean	SD	Loadings	Cronbach's α	CR	AVE
Growth mindset	GM1.	3.359	0.766	0.780	0.742	0.848	0.650
	GM2.	3.358	0.775	0.809			
	GM3.	3.455	0.762	0.830			
Mathematics self-efficacy	MSE1.	2.468	0.695	0.724	0.925	0.936	0.622
	MSE2.	2.401	0.700	0.751			
	MSE3.	2.397	0.697	0.807			
	MSE4.	2.389	0.675	0.745			
	MSE5.	2.496	0.705	0.845			
	MSE6.	2.480	0.714	0.812			
	MSE7.	2.483	0.719	0.822			
	MSE8.	2.373	0.703	0.742			
	MSE9.	2.565	0.736	0.837			
Perspective-taking	PT1.	3.600	0.813	0.723	0.737	0.835	0.558
	PT2.	3.935	0.723	0.729			
	PT3.	3.767	0.789	0.766			
	PT4.	3.714	0.789	0.770			

reliability according to Hair et al. (2019). Moreover, the Average Variance Extracted (AVE) for each construct is more than the threshold value of 0.50 recommended by Hair et al. (2019), thus the model in this study has a good convergent validity. Furthermore, the constructs in this study have good internal consistency reliability, with Composite Reliability (CR) ranging from 0.835 to 0.936 as indicated by Hair et al. (2019) (see Table 2).

Discriminant validity was assessed using the HTMT criterion and the Fornell-Larcker criterion. Results of the HTMT correlation ratio test are shown in the upper off-diagonal matrix in Table 3, which indicates estimated correlations among constructs and falls below the threshold of 0.90, marked as the HTMT threshold (Henseler et al., 2015). Additionally, this study also applied the criterion for establishing discriminant validity as the square root of the AVE, as manifested by the diagonal values being higher than that of the inter-construct correlations as supported by the smaller off-diagonal values (Fornell & Larcker, 1981).

3.2. Structural model analysis

The following is the assessment of the structural model in this study: the coefficient of determination, a validated cross-validated redundancy measure Q^2 based on blindfolding, and the statistical significance together with the relevance of the path coefficients. Before assessing the structural model, VIF analysis was conducted to ensure that the constructs are free from collinearity. As depicted in Table 3, VIF values for each construct are below the threshold value set at 3 (Hair et al., 2019).

Next, taking into account the R^2 value, it may be supported that, together, growth mindset, mathematics self-efficacy, and perspective-taking explain 27.2% of the variance in math performance after controlling for the ESCS variable, gender, and the proportion of teachers with at least a master's degree. This finding provides an acceptable R^2 value in the educational context for the prediction of human perceptions (Hair et al., 2019). The Stone-Geisser test criterion (Q^2) is greater than 0

Table 5 Direct effects

Hypothesis	Path	β	t statistics	Results
H1	GM -> MA	0.227***	21.516	Supported
H2	PT -> MA	0.228***	20.296	Supported
H3	MSE -> MA	0.084***	7.922	Supported

*** $p < 0.001$

Table 6 Indirect effects

Hypothesis	Path	β	t statistics	Results
H4	GM -> MSE -> MA	0.003**	2.612	Supported
H5	PT -> MSE -> MA	0.013***	6.663	Supported

** $p < 0.01$;*** $p < 0.001$

for all dependent variables, which upholds the moderate predictive relevance of the structural model (Hair et al., 2019). Table 4 depicts the complete results of the evaluation of the structural model. The results presented in Table 5 show that GM has a positive and significant effect on math achievement (MA) (β = 0.227***), thus supporting H1. Similarly, PT and MSE have positive and significant effects on MA (β = 0.228***; β = 0.084***), thereby supporting H2 and H3. Furthermore, the results presented in Table 6 indicate that MSE mediates the relationship between GM and PT with MA (β = 0.003**; β = 0.013***), thus supporting H4 and H5.

Given the significance of mathematical competence for high school students, it is crucial to understand the factors that can sustain or enhance this competence. Among the various factors, psychological research highlights the roles of growth mindset and perspective-taking in directly predicting students' mathematics achievement. Therefore, the primary objective of this study is to investigate the roles of growth mindset and perspective-taking, in addition to mathematics self-efficacy, in math performance among high school students.

3.4. Growth mindset and mathematics achievement

Based on the findings of this study, growth mindset has a positive and significant impact on students' mathematics achievement. Therefore, it was validated that growth mindset is one of the social-emotional competencies crucial to improving the mathematics achievement of high school students. Individuals with a growth mindset are less likely to quit when challenged; rather, they have more ability to overcome

Table 3 Discriminant validity: HTMT and Fornell Larcker criteria

	Mean	SD	GM	MSE	PT	MA
GM	3.390	0.623	**0.807**	0.063	0.109	0.260
MSE	2.450	0.558	0.034**	**0.788**	0.169	0.152
PT	3.754	0.582	-0.081**	0.140**	**0.747**	0.330
MA	391.640	61.917	0.224**	0.147**	0.284**	**1.000**

** $p < .01$

Table 4 Colinearity, predictive accuracy, predictive relevance, and goodness of fit

Dependent	Independent	VIF	R^2	R^2 adj	Q^2
GM		1.017			
PT	MA	1.081	0.272	0.271	0.263
MSE		1.034			

Goodness of fit: χ^2 = 6794.959; NFI = 0.893; SRMR = 0.053

school hurdles and believe that failure is an avenue to learning (Yeager et al., 2019; Qin et al., 2021). Consequently, students with a growth mindset will be more motivated and resilient in the face of academic difficulties, which may, in turn, improve their academic performance.

3.5. Perspective-taking and mathematics achievements

This research established that perspective-taking has a positive and significant effect on high school students' mathematics achievement. By such a finding, it was confirmed that this ability is one of the social-emotional competencies necessary to improve students' math performance. Students with perspective-taking skills will be in a better position to collaborate and build important social skills within a learning environment. This is supported by Qin et al. (2021). Therefore, developing the ability of perspective-taking in the high school level will result in not only improved peer relationships but also increased math achievement.

4.6. Growth mindset, perspective-taking, and mathematics self-efficacy

This research supports that the effect of growth mindset and perspective-taking on mathematics achievement can be mediated by mathematics self-efficacy to a moderate extent. This implies that advocating for the growth mindset and perspective taking alone is insufficient to improve students' performance in mathematics to the desired level. Research has further supported this view stating; for instance, self-efficacy is paramount to students' academic achievement (Pajares & Miller, 1994; Bandura, 1997). Therefore, programs geared towards the teaching of mathematics should aim at building the mathematics self-efficacy of the students as such training arms the individuals with effective coping skills in the face of difficulties (Schunk & Pajares, 2002). Furthermore, it will also be best if these programs also aim at fostering a growth mindset and perspective taking skills together with self-efficacy enhancement.

4. Implications for educational practice

The fact that certain characteristics like growth mindset, skills for perspective-taking, and math self-efficacy have a huge weight in the achievement of mathematics goals reminds teachers of what to pay particular emphasis on. It implies that teachers need to instill these attributes in students to improve their mathematics performance.

To start with, it is very important to encourage the students to adopt a growth mindset. This is that mindset that helps individuals understanding that nothing is cast in stone, and with practice and dedication, one can learn and master any skill, even the most difficult one, like mathematics. Teachers can sustain this perspective by encouraging students to embrace more the effort than the innate gifts and talents, by praising them for being appreciative of effort rather than ability, and by giving evaluations that are more concerned with process than product (Dong et al., 2023). This approach serves to improve the performance of the students in mathematics as well as help reduce the impact of negative stereotypes about intelligence, thereby fostering fairness in the education system.

On another note, it is important to include perspective-taking skills in the teaching of math. This is so because students need to be able to understand other people's thinking processes and ways of solving problems, which gives them the

cognitive and creative skills every student needs when doing maths, reasoning, and solving problems. Teachers can use activities that require students to think of their thoughts, processes in solving the problem, and other ways of solving the problem in order to understand better the concepts in mathematics.

Another area of concern is self-efficacy in mathematics, which is an important factor that aids the link between growth mindset, perspective-taking and math success. Self-efficacy refers to any student's belief about his or her capacity to perform given tasks. This belief can be promoted by encouraging students to work hard but also setting attainable goals, praising them depending on their abilities, and creating a classroom setting where students are encouraged to fail and learn from their failures (Fernández-Méndez et al., 2020). The increase in this kind of confidence encourages students to face challenges more and reduces mathematics anxiety.

To conclude, educational provision must be directed towards developing a growth mindset, perspective-taking skills, and mathematics self-efficacy in students. These techniques will not only improve the mathematics ability of the students but will also impart them with skills that will help them as they grow. There are a lot of benefits for both students in terms of advancement and development, and teachers when effort, opinion diversity, and self-esteem about mathematics insistence are practiced within the classroom by the teacher.

5. Conclussion

This investigation focuses on the importance of growth mindset, perspective-taking skills, and self-efficacy in mathematics as factors that enhance the level of mathematics achievement among high school students. This study investigates the students' social and emotional skills, such as growth mindset and perspective-taking, and establishes them as factors that influence the students' performance in mathematics. It has been shown that students with a growth mindset don't shy away from challenges as much as their non-growth-minded peers, since they believe such challenges only serve to teach them and therefore help them stay focused and motivated to accomplish their goals. Moreover, when students are able to take the perspective of others, this skill aids in the students' ability to work together and develop social skills, which is favorable for mathematics performance.

Moreover, in this research study, it was established that self-efficacy in mathematics is a partial mediator between growth mindset, perspective-taking abilities, and mathematics achievement. This indicates that encouraging growth mindset and perspective-taking skills is worthwhile, but it is not enough to fully optimize students' performance in mathematics. This is critical, especially since one's motivation and perseverance in the face of difficulty are significantly affected by one's self-efficacy in mathematics.

To sum up, educational systems ought to focus on promoting growth mindset, perspective-taking, and mathematics self-efficacy in the students. Infusing these components into the educational atmosphere can place the students' mathematics performance on a higher level and prepare them with essential lifelong skills. Such an approach does not only propagate academic excellence but personal development as well, through establishing an environment that is characterized by hard work, appreciation of different viewpoints, and belief in oneself in relation to math.

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