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Metacognition and Achievement Emotions in Mathematical Modelling Competency: A Confirmatory Factor Analysis of Their Interplay

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Abstrak

Penelitian ini menyelidiki hubungan antara metakognitif dan pencapaian emosi dalam pemodelan matematis pada siswa di sebuah SMA Negeri yang berlokasi di Kabupaten Karawang. Penelitian ini melibatkan 200 siswa. Penelitian ini menggunakan desain penelitian korelasional untuk mengetahui hubungan antara metakognitif dan pencapaian emosi dengan menggunakan teknik analisis yaitu analisis faktor konfirmatori. Selain itu, terdapat empat faktor metakognitif termasuk *awareness, cognitive strategy, planning,* dan *self-checking* serta dua faktor pencapaian emosi *Joy* dan *Pride* yang memiliki hubungan signifikansi sebesar 0,72 sehingga terdapat hubungan yang signifikan antara metakognitif dan emosi. Terdapat faktor *planning* sebagai faktor dominan metakognitif dan faktor *pride* sebagai faktor dominan pencapaian emosi yang memiliki hubungan antar satu sama lain.
Kata Kunci: analisis faktor konfirmatori; *awareness*; emosi; *joy; pride;* pemodelan matematis

Abstract

This study aims to examine the relationship between metacognition and achievement emotions in the context of mathematical modeling among students at a public senior high school in Karawang Regency. A total of 200 students participated in the study. The research employed a correlational design, utilizing confirmatory factor analysis (CFA) to analyze the relationship between the two constructs. Metacognition was measured through four factors: awareness, cognitive strategy, planning, and self-checking. Achievement emotions were represented by two factors: joy and pride. The analysis revealed a significant correlation of 0.72 between metacognition and achievement emotions. Furthermore, planning was identified as the most dominant factor within the metacognitive domain, while pride emerged as the dominant factor within the domain of achievement emotions. These two dominant factors were also found to have a significant relationship with one another.
Keywords: awareness; confirmatory factor analysis; emotion; joy; mathematical modeling; pride

I. Introduction

The ability to model mathematically is an essential competency that students must possess because this skill enables them to connect mathematics with real-world situations (Farida & Hakim, 2021). This is due to the important role of mathematical modeling skills in supporting students to solve problems related to real-world situations. In solving real-world problems (Permatasari & Harta, 2018; Puspita, Herman, & Dahlan, 2023). Mathematical modeling is not only related to the use of formulas or solving problems, but also includes the ability to understand and translate real problems into mathematical models, solve those models, and interpret the solutions obtained in the context of the original problem (Hidayat et al., 2018; Vorholter, 2019; Zulkarnaen, 2020).

Several studies have shown that students' ability to perform mathematical modeling involving word problems remains low due to the complexity of the mathematical modeling process (Kartal et al., 2016; Yew & Akmar, 2016; Hidayat et al., 2018). This statement aligns with the findings of Turrosifah & Hakim (2020), which reveal that students continue to experience difficulties in formulating mathematical models and representing everyday events in mathematical symbols, which are integral to the stages of the mathematical modeling process.

PISA findings from recent years indicate that Indonesian students often encounter difficulties with questions that require higher-order thinking skills, particularly in converting contextual situations into mathematical models (Dwirahayu, 2018; Mutiakandi & Sari, 2024). This low level of competence indicates that problems in mathematical modeling are not solely related to mastery of concepts, but also reflect challenges in students' self-regulation and affective aspects.

Mathematical modeling is a complex process that requires not only conceptual knowledge (Khusna & Ulfah, 2021) but also the skill of consciously managing thinking strategies (metacognition) and the ability to manage emotions that arise during the problem-solving process. Several studies have shown that success in mathematical modeling is significantly influenced by students' metacognitive abilities to plan, monitor, and evaluate their approach to a problem (Setyaningrum & Mampouw, 2020; Fathurrohman, 2020; Galbraith, 2017).

In addition, recent developments in educational psychology show that emotional achievements, such as feelings of pride or joy while learning, contribute to academic success, including in mathematics (Camacho-Morles et al., 2021; Bieleke et al., 2023). For example, Camacho-Morles et al. (2021) confirmed through a meta-analysis that emotions play a crucial role in both motivational and self-regulation processes, which are key aspects of metacognitive activities. In other words, students who feel confident and proud of their academic achievements will be better able to manage their thinking processes reflectively and strategically. Conversely, negative emotions such as anxiety can hinder working memory and mathematical thinking processes (Huang, 2011; Passolunghi et al., 2020), thereby affecting success in modeling.

Metacognition is defined as an individual's knowledge or activities related to understanding and managing their own thinking processes and outcomes, or internal aspects of themselves (Flavell, 1976). Metacognition broadly encompasses two aspects: metacognitive knowledge, or awareness of learning and thinking strategies, and metacognitive regulation, which involves the effective control of the learning process. Metacognitive abilities require not only mastery of mathematical concepts but also higher-order thinking skills, such as reflection and evaluation (Lesh & Zawojewski, 2007). These steps are part of metacognition. For example, metacognition influences students' strategies in mathematical modeling, including planning, cognitive strategies, and self-checking (Yildirim, 2011). When students can plan in mathematical modeling, they will exhibit an increase in modeling competency growth (Hidayat et al., 2020). In other words, students with good metacognition can determine whether the chosen strategy yields effective results; if not, they can adjust their approach to improve it.

Research indicates that students with higher levels of metacognitive ability tend to demonstrate greater success in solving complex mathematical problems (Yoong, 2002). They can formulate appropriate questions, manage their time well, and evaluate solutions critically. In the context of mathematical modeling, this ability is essential because students must constantly monitor whether the models they construct are suitable for the problems they encounter and whether the solutions obtained can be applied in real-world contexts (Hidiroglu & Bukova-Güzel, 2016). In learning, other factors can influence students' mathematical abilities, namely affective factors (Nabillah & Abadi, 2020).

In the learning process, affective factors such as emotions often determine the extent to which students can absorb and understand the material. Positive emotions can increase learning engagement, while negative emotions, such as anxiety, can actually hinder it. Emotional achievement plays a significant role in students' learning and influences their mathematical abilities (Pekrun et al., 2017).

Pekrun (2006) categorizes emotional achievement as pure emotions that correspond to learning activities or the results of those activities. Emotional achievement encompasses a range of positive emotions, such as pride, joy, and satisfaction, as well as negative emotions, including anxiety, frustration, and fear of failure. Both types of emotions can influence student engagement and performance in mathematical modeling. The theory posits that these emotions are influenced by cognitive control assessments before, during, and after the activity (Pekrun, 2006).

Positive emotions such as joy and pride tend to increase students' motivation to engage more deeply with challenging tasks, including mathematical modeling. Students who take pride in their progress in understanding mathematical concepts will be more motivated to solve increasingly complex problems (Camacho-Morles et al., 2021). Conversely, negative emotions such as anxiety can hinder students' thinking. Math anxiety can interfere with concentration, cause students to doubt their own abilities, and ultimately reduce students' ability to perform mathematical modeling (Huang, 2011).

The relationship between emotional achievement and mathematics learning outcomes has been extensively studied in various research studies. This is in line with the research by Camacho -Morles (2021) using meta-analysis in his research, which states that emotional achievement is related to academic, work, or sports activities (activity emotions) and the results of success and failure (outcome emotions) and shows that emotional achievement is related to the processes of motivation, self-regulation, which is included in metacognition, and cognition, which are important for academic success. This suggests that enhancing mathematical modeling skills necessitates improvements in teaching strategies and also in managing students' emotions during the learning process.

Although metacognition and emotional achievement are two different factors, they are interrelated in the learning process. Students with higher metacognitive abilities generally have better control over their emotions when faced with complex tasks. Therefore, the objectives of this study are:

1. Is there a significant relationship between metacognitive factors and emotional achievement factors in mathematical modeling?
2. Which factors are most dominant in metacognition and emotional achievement in mathematical modeling?

Thus, the hypotheses in this study are:

H0: There is no significant relationship between the factors of awareness, cognitive strategy, planning, and self-checking with the factors of Joy, Anxiety, and Pride in mathematical modeling.

H1: There is a significant relationship between the factors of awareness, cognitive strategy, planning, and self-checking with the factors of joy, anxiety, and pride in mathematical modeling.

H2: There is a most dominant factor in metacognition and a most dominant factor in emotional achievement.

II. Method

The correlational research design was employed in this study to identify and analyze the relationships between the variables under investigation. In data collection, this study used mathematical modeling test instruments, metacognitive questionnaire instruments, and emotion achievement questionnaire instruments.

This study employs a multivariate method, utilizing a confirmatory factor analysis technique. Confirmatory factor analysis serves to verify the suitability of the developed measurement model with the structure formulated in the hypothesis (Juilda et al., 2016). In multivariate analysis, sample size plays an important role. Sugiyono (2014) suggested that the ideal sample count should be at least ten times the number of variables analyzed to obtain valid and reliable results. Therefore, with a total of seven factors studied, the minimum number of samples required is 70 respondents. Referring to this opinion, the minimum sample size has been fulfilled with a total sample of 200 students in one of the high schools in Karawang Regency.

Data analysis was conducted using JASP software version 0.19.3.0. The Confirmatory Factor Analysis (CFA) procedure was conducted using maximum likelihood estimator settings. The goodness-of-fit assessment referred to the Chi-square index ($p > 0.05$), CFI > 0.90, NFI > 0.90, and RMSEA < 0.08 (Hair et al., 2010). In addition, values of CA and CR in the range of 0.60-0.70 can be considered reliable, while AVE must be greater than 0.50.

The mathematical modeling test is the first instrument in this study, which is designed with the context of real-world situations to evaluate students' ability to perform mathematical modeling. The mathematical modeling test instrument used was adopted from Zulkarnaen (2020) and contains questions related to maximum and minimum value materials.

The second instrument used in this study is a metacognitive questionnaire that aims to measure students' level of awareness and self-control in their thinking process. The metacognitive questionnaire was originally created by O'Neil & Abedi (1996) which was modified and used by Yildirim (2011) in mathematical modeling. In this study, the researcher made further adjustments to the wording of the statement to suit the context of Indonesian high school students and the context of the mathematical modeling test used. These adjustments include changing diction, simplifying language, and linking it to activities to work on contextual modeling problems.

The metacognitive questionnaire consisted of four factors, each comprising 20 statements, with five statements per factor. Factors in these instruments are awareness (I am aware of what kind of mathematical modeling I am using and when I use it), cognitive strategy (I am trying to find the main way to do the test), planning (for example, I try to understand the purpose of the test before trying to complete it), and self-checking (I always double-check my answers).

The assessment was conducted using a 5-point Likert scale, with a score range from 1 (strongly disagree) to 5 (strongly agree). The selection of the 5-point scale was based on considerations of ease of understanding for high school level respondents and to minimize the ambiguity that often occurs on larger scales (such as 7 or 10 points), while maintaining the sensitivity of the measurement to attitude variations.

The third instrument used in this study is an Emotional Achievement Questionnaire, designed to assess students' emotional experiences in the context of mathematics learning. The Emotional Achievement Questionnaire used in this study was adopted from Bieleke et al. (2023). The Emotion Achievement Questionnaire consisted of three factors, each comprising six statements. The factors in the instrument are joy (for example, I enjoy learning math), anxiety (for example, when I do math problems, I feel my heart pounding and panic), and pride (I am proud of my ability in math lessons).

Then, the instrument was distributed to one of the State High Schools in Karawang

Regency with the help of Google Forms. Participation is carried out after obtaining approval from the school as a representative of the institution and confirmation of consent from the participants. Data were analyzed using confirmatory factor analysis to examine the metacognitive relationship and emotional achievement in mathematical modeling, as well as the most dominant factors on metacognitive and emotional achievement.

III. RESULT AND DISCUSSION

After the data is collected, processing is carried out using confirmatory factor analysis to build the correct measurement model, as well as to evaluate the validity and reliability of the model. The initial models of this study are presented in Figure 1.

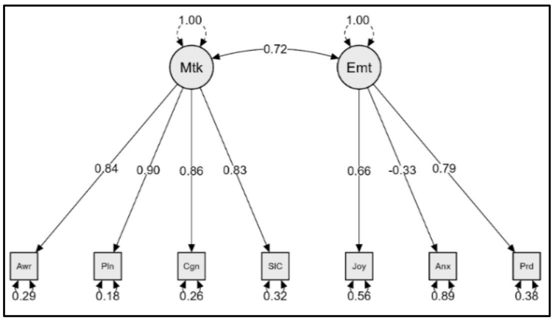

Figure 1. Metacognitive-Early Models and Emotional Achievement

In Figure 1, it can be seen that the initial metacognitive model consists of four factors, namely awareness (Awr), planning (Pln), cognitive strategy (Cgn), and self-checking (SIC). In addition, the achievement emotions model consists of three factors, namely joy (Joy), anxiety (Anx), and pride (Prd). The feasibility of the model in Figure 1 is determined by the fulfillment of the assumptions of normality, goodness of fit, and adequate validity and reliability By using JASP software, the results of the normality, goodness of fit, and validity and reliability values presented in Table 1, Table 2, and Table 3 are obtained.

The results of the normality test are presented in Table 1.

Table 1.
Normality Test Results

Normality	Awr	Pln	Cgn	SIC	Joy	Anx	Prd
Shapiro-Wilk	0,972	0,962	0,964	0,982	0,991	0,986	0,988

It can be seen in Table 1 that the distribution of the data approaches normality, as indicated by a value of 1. The data on the modified model of the early model meet the assumption of normality. Furthermore, it was tested for goodness of fit. The results are presented in Table 2.

Table 2.
Goodness of Fit Test Results

Conformity Index	Measurement Values
Chi-square	20,116
CFI	0.990
RMSEA	0,052
NFI	0,973

Using a significance level of 0.05 and a degree of freedom of 13, the cut-off value for the chi-square match index is 20.116. Based on the data in Table 2, the CFI value > 0.90, RMSEA < 0.08, and NFI > 0.90. Thus, the model shown in Figure 1 can be categorized as having a good level of fit. Furthermore, testing was carried out on the validity and reliability of the model, the results of which are presented in Table 3.

Analysis of the measurement model is carried out through validity and reliability testing. Validity testing includes convergent and discriminant validity, which is assessed based on the Average Variance Extracted

(AVE) value. Meanwhile, reliability testing includes construct reliability, which is measured using both Composite Reliability (CR) and Cronbach's Alpha (CA).

Table 3.
Validity and Reliability Test Results

Factor Loading	
Metacognitive (Mtk); CA = 0.918; CR = 0.918; AVE = 0.739	
Awareness	0,858
Cognitive Strategy	0,844
Planning	0,904
Self-Checking	0,827
Emotional Achievement (AcE); CA = 0.023; CR = 0.386; AVE = 0.379	
Joy	0,663
Anxiety	-0,327
Pride	0,787

Based on Table 3, it can be seen that the emotional achievement has a validity value of AVE = 0.379 < 0.5, a CA value = 0.023 < 0.60, and a CR = 0.386 < 0.7. The initial model proposed in this study shown in Figure 1) consists of four metacognitive factors (awareness, planning, cognitive strategy, self-checking) and three factors of emotional achievement (joy, anxiety, pride).

However, based on the results of the validity and reliability tests presented in Table 3, it was found that the anxiety factor had a negative loading factor value of -0.327, an average variance extracted (AVE) value of 0.379, and a Cronbach's alpha (CR) value of 0.386. The three values are below the minimum eligibility threshold, specifically FL < 0.5, AVE < 0.5, and CR < 0.7. This indicates that the anxiety construct has not yet met the validity and reliability requirements necessary for the measurement model. Therefore, the anxiety factor was excluded from the model because it did not meet convergent validity and was not statistically reliable.

The exclusion of the anxiety factor yields a simpler and more stable final model, as shown in Figure 2, which retains only two factors of emotional achievement: joy and pride. The final model is then re-evaluated to test the goodness of fit and measurement quality.

In Figure 2, it can be seen that metacognition is explained by four factors, namely awareness (Awr), planning (Pln), cognitive strategy (Cgn), and self-checking (SlC). In addition, emotions are explained by two factors, namely joy (Joy) and pride (Prd). A model, as shown in Figure 2, is considered good if it meets the assumption of normality, has an appropriate measure of goodness of fit, and has been tested for validity and reliability.

The results of the normality test are shown in Table 4.

Table 4.
Normality Test Results

Normality	Awr	Pln	Cgn	SlC	Joy	Anx	Prd
Shapiro-Wilk	0,972	0,962	0,964	0,982	0,991	0,986	0,988

Description : Awr (*awareness),* Cgn (*cognitive strategy),* Pln (*Planning*), SlC (*self-checking*), Prd (*pride*).

As shown in Table 4, the data distribution is standard, with a value close to 1. The data on the modified model of the early model meet the assumption of normality. Furthermore, it was tested for goodness of fit. The results are presented in Table 5.

Table 5.
Goodness of Fit Test Results

Conformity Index	Measurement Values

Conformity Index	Measurement Values
Chi-square	17,826
CFI	0,986
RMSEA	0,078
NFI	0,976

Based on Table 2, the CFI value is greater than 0.90, the RMSE is less than 0.05, and the NFI is greater than 0.90; therefore, the model shown in Figure 2 can be said to have an adequate level of goodness of fit. Furthermore, validity and reliability tests were carried out, with the results presented in Table 6.

The validity and reliability of the measurement model are analyzed to ensure the quality of the instrument. Convergent and discriminant validity are assessed through AVE values, which indicate the extent to which each indicator represents its corresponding construct. Construct reliability is tested through CR and CA values to assess the internal stability and consistency between items in a single construct.

Table 6.
Validity and Reliability Test Results

Factor Loading	
Metacognitive (Mtk); CA = 0.918; CR = 0.918; AVE = 0.739	
Awareness	0,858
Cognitive Strategy	0,844
Planning	0,904
Self-Checking	0,827
Emotional Achievement (AcE); CA = 0.686; CR = 0.692; AVE = 0.531	
Joy	0,666
Pride	0,784

Table 6 shows that the entire loading factor value is above 0.5, the CA value exceeds 0.6, the CR value is more than 0.6, and the AVE value also exceeds 0.5. These findings indicate that the model used has met the criteria for validity and reliability. In addition, because the model also meets the assumption of normality and has a good measure of goodness of fit, the model in Figure 2 is declared worthy of further interpretation.

The model in Figure 2 illustrates that metacognition is influenced by four factors: awareness, cognitive strategy, planning, and self-checking. In contrast, emotional achievement consists of two dominant factors: joy and pride. The results showed that planning had the most significant contribution to metacognitive constructs (β^2 = 0.817), and pride was the most dominant factor in emotion (β^2 = 0.615). Both play an important role in students' ability to solve mathematical modeling problems strategically and confidently.

However, it is essential to note that the anxiety factor was excluded from the model due to its negative factor loading value (-0.327) and the non-fulfillment of the reliability and validity criteria for the construct. This suggests that students' responses to anxiety items are inconsistent, or that the measurement context is not strong enough to give rise to significant differences in anxiety perception. Another possibility is that students are not yet aware of the impact of negative emotions on their performance explicitly, or that local cultural factors can influence how negative emotions such as anxiety are expressed.

Theoretically, anxiety remains relevant in the study of learning mathematics. Therefore, further research needs to re-investigate the measurement of anxiety with a qualitative or longitudinal approach, as well as consider local validation strategies for items adopted from the international literature. However, to complete the conceptual study, a quantitative analysis is necessary to determine the magnitude of each factor's contribution to the construct being studied. The magnitude of the influence of each of these factors on the construct is presented in Table 7.

Table 7.
The Big Influence of Metacognitive and Emotional Achievement

Construct	Factor	Squared Multiple Correlation
Metacognitive	Awr	0,736
	Cgn	0,712
	Pln	0,817
	SlC	0,684
Achievement	Joy	0,443
Emotion	Prd	0,615

Description: Awr (*awareness),* Cgn (*cognitive strategy),* Pln (*Planning*), SlC (*self-checking*), Prd (*pride*).

Table 7 shows that metacognition is influenced by awareness (Awr) by 74%, cognitive strategy (Cgn) by 71%, planning (Pln) by 82%, and self-checking (SlC) by 68%. The findings of Hidayat et al. (2018) in their research stated that metacognition in mathematical modeling can be influenced by how students carry out their own thinking constructs when working on problems.

In addition, several studies have shown that good metacognition skills are necessary for working on mathematical modeling problems (Safitri et al., 2020), with planning being the most dominant factor in metacognitive ability.

This aligns with research (Hidayat et al., 2020) indicating that students must plan their approach to mathematical modeling problems before tackling them to achieve optimal results. In addition, Table 7 also shows that emotional achievement is influenced by joy (Joy) by 44% and pride (Prd) by 62%. This result aligns with Pekrun's (2006) theory, which suggests that students' positive emotions and pride in working on mathematical modeling problems lead to better learning outcomes.

This suggests that students with good metacognitive abilities will take pride and joy in working on mathematical modeling problems, with pride being the dominant factor in their emotional achievement. This is in line with research (Sutrisno & Yusri, 2021) that students who have a sense of pride in themselves when working on mathematical modeling problems will have better learning outcomes.

Based on Figure 2, it can be seen that metacognitive and emotional achievement have a relationship of 0.72. Thus, these results indicate a significant relationship between the two analyzed constructs. This aligns with Pekrun et al.'s (2017) research, which suggests that when students experience positive emotions (such as enjoyment of learning and pride) during learning, they tend to better plan when tackling problems. Students can develop their problem-solving skills, and vice versa. However, when students experience negative emotions, it is expected to negatively impact their achievement. Metacognition processes have a relationship with emotions because there is a connection between the dominant factors in metacognition processes and students' emotions.

When students feel proud of their previous achievements, this emotion can encourage them to be more serious in planning when working on mathematical modeling problems. Pride in good results or past successes will strengthen intrinsic motivation, encourage them to prepare better and do more thorough planning (Lazarides & Buchholz, 2019). In addition, feeling proud often contributes to increased self-confidence.

When students feel proud, they are more likely to be optimistic and feel more confident in designing the steps needed to solve the problem. This confidence has an impact on improving the quality of planning because students feel able to face challenges in complex mathematical modeling problems (Chen et al., 2020). This study shows that there is a relationship between metacognitive ability and students' emotional achievement in mathematical modeling.

IV. Conclusion

The results of this study provide further evidence that metacognition has a positive relationship with emotional achievement in mathematical modeling. In addition, the four metacognitive factors, namely awareness, cognitive strategy, planning, and self-checking, are partial mediators. Meanwhile, in the achievement of emotions, there are two partial mediators, namely joy and pride. According to the study's results, planning and pride are the primary factors influencing metacognitive and emotional achievement. This suggests that Shiva's ethics fosters reasonable emotional control, characterized by pride in oneself and pleasure derived from working on mathematical modeling problems. Consequently, students will develop strong metacognitive thinking skills.

When students have a sense of pride in previous successes or achievements, they tend to be more confident and motivated to engage in a deeper thought process. These positive emotions reinforce students' desire to try harder, including in organizing, monitoring, and evaluating the steps that have been made. Thus, the interaction between metacognitive and emotional achievement is key to achieving better results in mathematical modeling because they serve as complementary foundations in achieving a more profound understanding and higher achievement.

Based on these findings, concrete steps that can be applied in the field are to encourage teachers to integrate metacognitive training in the mathematics learning process, for example, by guiding students to make plans before completing problems, monitoring their thinking processes, and reflecting after completing assignments.

Although the results of this study support the relationship between metacognitive and emotional achievement, there are limitations in terms of cross-sectional research design and homogeneous sample representation. Therefore, further research is recommended to use a longitudinal design to capture the dynamics of metacognitive and emotional relationships more deeply over time. In addition, a mixed-methods approach that combines quantitative and qualitative data is also recommended in order to explore students' psychological context more holistically, including how negative emotions such as anxiety can arise

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and affect their thought processes in real-life situations.

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