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# Metacognition's Mediating Effect on Undergraduate Achievement Goals and Mathematical Modelling Competency

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The purpose of this research is to investigate the influences of achievement goals and metacognition on mathematical modelling competency among undergraduates, with a specific focus on understanding the mediating role of metacognition in the relationship. This quantitative study employed a cross-sectional survey research design. Cluster sampling method was used to select 694 undergraduates majoring in mathematics in Hebei province, China, including 522 (75.2%) females and 172 (24.8%) males. Participants are between 18 and 22 years old. To collect data, the mathematical modelling competency test questionnaire, metacognition inventory and achievement goals scale were used. Amos 28.0 was used to analyse the data through a structural equation model. The results of this research suggest that both achievement goals and metacognition have a positive influence on mathematical modelling competency. Metacognition has a partial mediating effect on the relationship between achievement goals and mathematical modelling competency. The study concludes that teachers should focus on undergraduate metacognition and goal-oriented guidance to further cultivate their mathematical modelling competency.

Keywords: mathematical modelling competency, metacognition, achievement goals, mediating effect, undergraduate

## INTRODUCTION

Many real-world problems are extremely complex. In fields such as economics, engineering, and social sciences, problem-solving often requires thorough analysis and multifaceted prediction. Students with mathematical modelling competency can transform these challenging real-world problems into mathematical models, facilitating systematic examination and problem-solving (Geiger et al., 2017). For instance, mathematical models were essential in forecasting the spread of the COVID-19 virus

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and developing countermeasures during the pandemic. Students possessing mathematical modelling competency in higher education are thought to be capable of performing successful scientific research because this talent entails rigorous scientific methodologies. According to earlier studies, undergraduates struggle to turn real-world settings into mathematical frameworks. For example, Gainsburg (2008) investigated how students translated mathematical difficulties into real-world situations. Her research showed that when it comes to practical applications, students find it difficult to convert real-world scenarios into mathematical models. To improve undergraduate mathematical modelling competency, studies first need to clarify the factors and mechanisms that influence undergraduate mathematical modelling competency.

The theory of problem-solving suggests that motivation, emotion, cognition, environment, and other variables influence students' problem-solving processes (Voica et al., 2020). Mathematical modelling refers to the methodology by which students apply mathematical knowledge to solve real-world problems. Therefore, it is believed that mathematical modelling competency will be affected by many factors. Although many researchers have been trying to identify the factors that affect students' mathematical modelling competency for many years, the role of the factors that affect students' mathematical competencies to solve reality problems is still not very clear (Schukajlow et al., 2011). Hidayat et al. (2023) analysed the relationship between a single factor and mathematical modelling competency, however, the impact on mathematical modelling competency should be a very complex mechanism. Hassana et al. (2013) have analysed factors that affect students' mathematical performance, but the research didn't focus on mathematical modelling. While Aydin-Güç and Baki (2018) examined the potential influence of variables on mathematical modelling competency, they did not employ empirical research methodologies to evaluate these impacts.

Previous studies have examined several aspects that impact students' mathematical modelling competency. Metacognition is the ability of an individual to regulate his own cognitive process. In the process of mathematical modelling, it is necessary not only to master mathematical knowledge, but also to effectively plan, monitor and reflect on their problem-solving strategies and processes. Achievement goals emphasize students' motivation and goal orientation in the learning process. Studies have shown that achievement goals play a key role in the problem-solving process. However, there is a clear lack of study on the combined influence of metacognition and achievement goals on mathematical modelling competency. Furthermore, the function of metacognition as a mediating element in this situation has not been thoroughly investigated. The purpose of this study is to examine the impact of metacognition and achievement goals on undergraduate mathematical modelling competency to fill these existing gaps. The present work used a structural equation modelling (SEM) methodology to examine the intricate interconnections among achievement goals, metacognition, and mathematical modelling competency. This study offers empirical evidence on the mediating function of metacognition, which not only enhances the theoretical understanding of mathematical modelling competency but also provides practical directions for educators seeking to improve students' problem-solving abilities through focused interventions.

Given the information provided, the present study seeks to address the following research questions:

1.Do achievement goals significantly influence mathematical modelling competency among undergraduates?

2.Does metacognition significantly influence mathematical modelling competency among undergraduates?

3.Does metacognition mediate the relationship between achievement goals and mathematical modelling competency?

**Review of Literature**

In recent years, the impact of motivation and cognition on students' problem solving has garnered increasing attention from researchers and educators alike. This literature review aims to examine the existing research on the influence of motivation and cognition, such as achievement goals and metacognition on mathematical modelling competency.

**The Influence of Achievement Goals on Mathematical Modelling Competency**

According to achievement goal theory (Chung et al., 2020), students who can set clear goals and regulate their learning processes tend to demonstrate stronger abilities in problem-solving. Existing research indicates that achievement goals can significantly influence students' learning motivation and behaviour (Pintrich & Schunk, 2002; Angraini & Wahyuni, 2021). Achievement goals encompass the specific aims and reasons that students strive for during their learning journey. These goals are commonly categorized into two types: mastery goals and performance goals (Grant & Dweck, 2003). Mastery goals prioritize enhancement of one's own skills and profound comprehension of knowledge, whereas performance goals prioritize the comparison of one's performance and achievements with others. According to Ergen and Kanadli (2017), mastery goals have a strong connection to students' drive to learn and their ability to regulate their own learning. This connection helps students develop persistence and patience when facing difficult mathematics problems. While performance goals might provide short-term motivation for students to attain favourable outcomes, their long-term impact may not be as substantial as that of mastery goals. According to Anderman & Patrick (2012)., performance goals can cause students to use surface learning tactics when they meet challenges, which can decrease their involvement and enthusiasm in mathematical modelling assignments. Within the field of mathematics education, English and Gainsburg (2015) investigated the significance of mathematical modelling as a crucial academic skill, which is affected by multiple factors. Nevertheless, there is a lack of evidence regarding the precise impact of achievement goals on students' mathematical modelling competency. While previous research has demonstrated a correlation between achievement goals and learning behaviour or academic success, the precise mechanism by mathematical modelling competency remains incompletely understood.

**The Influence of Metacognition on Mathematical Modelling Competency**

Metacognition is important for learning and problem-solving tasks which is when a person can observe and manage their own thinking processes. The concept of metacognition includes four main steps: planning, checking, cognitive strategy, and awareness. These steps let learners use what they know, change strategies, and work better when tasks are difficult (Pintrich, 2002). In math education, people have talked a lot about how important metacognition is. A study by Izzati and Mahmudi (2018) on solving math problems showed that metacognition is important in understanding problems. İdawati et al. (2020) also said that students who are good at using metacognitive strategies will be more flexible and better at solving math problems. In addition, Azevedo et al. (2017) pointed out that improving metacognitive skills can really help students be more self-regulated in digital learning, especially when the learning tasks are hard.

Mathematical modelling competency is a complex thinking process that involves using math knowledge to solve real-world problems (Cevikbas et al., 2021). Metacognition is very important in mathematical modelling because it requires not just a deep understanding of math knowledge but also the ability to use this knowledge in a flexible way, along with checking and controlling the modelling process at different points (English & Gainsburg, 2015).

Nevertheless, even though earlier studies have pointed out the importance of metacognition in dealing with mathematical problems, there is a noticeable shortage in the detailed literature about the exact impact of metacognition on mathematical modelling competency. Izzati and Mahmudi (2018) showed that the complexity and openness of tasks in mathematical modelling make metacognition more important in these tasks. But most existing research tends to focus more on how metacognition affects general mathematical ability, not on the specific way it works during the process of mathematical modelling. The exact way metacognition operates in mathematical modelling needs more study. It is necessary to investigate how metacognition influences students' performance on complex modelling tasks by affecting their emotions, motivations, and strategies in these tasks, providing stronger theoretical support and practical guidance for education.

**Metacognition as a Mediator of the Relationship Between Achievement Goals and Mathematical Modelling Competency**

Scholars have extensively examined and acknowledged the significance of metacognition in the processes of learning and problem-solving. This tool has a dual role of enabling students to control and oversee their cognitive processes throughout the learning process, as well as being essential for achieving the successful completion of intricate tasks (Pintrich, 2002; In 'am & Sutrisno, 2021). Achievement goal theory examines the diverse categories of objectives that students establish throughout the process of learning, which have a substantial impact on their motivation, learning habits, and ultimately their academic accomplishments.

Pintrich (2002) pointed out that students' achievement goals can indirectly affect their learning performance by influencing their use of metacognitive strategies. Students with mastery approach goals are more likely to use deep learning strategies and metacognitive monitoring, which helps them achieve better performance in complex tasks. It is worth affirming that metacognition plays an important role in bridging achievement goals and students' mathematical modelling competency. Mathematical modelling competency as a complex cognitive ability, involves converting real-world problems into mathematical forms and solving these problems (Cevikbas et al., 2021). This ability requires not only students to have solid mathematical knowledge, but also to be able to effectively regulate and monitor their cognitive processes and adapt to the changing task requirements in the modelling process (English & Gainsburg, 2015). Therefore, the role of metacognition in mathematical modelling is particularly important. Studies have shown that high levels of metacognitive ability can help students better understand problems, develop solutions, and evaluate the effectiveness of modelling results (Izzati & Mahmudi, 2018). However, although existing studies have explored the role of achievement goals and metacognition in general learning situations, research on how metacognition plays a mediating role in the process of achievement goals affecting mathematical modelling competency is still relatively limited. Some existing studies have shown that metacognition may play an important mediating role between achievement goals and mathematical modelling competency (Hidayat, Zulnaidi & Zamri, 2018), but systematic research in this area is still lacking.

**Research Purpose and Hypothesis**

Based on the above analysis, this study established a relationship model between achievement goals, metacognition and mathematical modelling competency (Figure 1). So, the purpose of this research is to test the relationship between achievement goals, metacognition and mathematical modelling competency, especially the mediating role of metacognition.

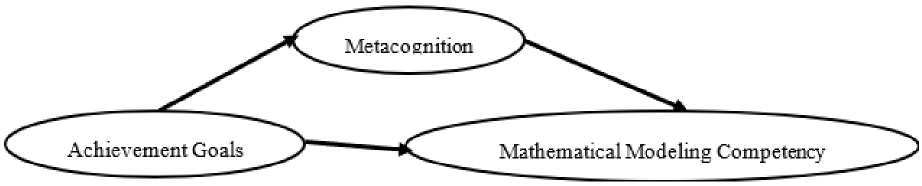


Figure 1
Hypothesis model

The followings are the research hypothesis.

Research hypothesis 1. Achievement goals have a significant positive influence on mathematical modelling competency among undergraduates.

Research hypothesis2. Metacognition has a significant positive influence on mathematical modelling competency among undergraduates.

Research hypothesis 3. Metacognition mediates the relationship between achievement goals and mathematical modelling competency.

## METHOD

### Participants

The appropriate authorities gave their consent for the study. The researchers then carried out a two-month survey at four Hebei Province universities. Students in Hebei Province majoring in mathematics made up this study's population. Since groups were chosen for the study rather than individuals, cluster random sampling is appropriate. 694 Hebei Province majors in mathematics participated in the current study. The participants were aged from 18 to 22 years, with 522 females (75.2%) and 172 males (24.8%). There were more female participants because of the gender gap in the mathematics major. Female students prefer to choose mathematics as their major so that they can become teachers in the future. Students from freshman to seniors in the academic year 2023–2024 were among those questioned. A letter outlining the purpose of the study, the tasks involved, the advantages and disadvantages of participation, and the confidentiality of the responses was sent to potential participants inviting them to participate in the research. During lecture hours, all the chosen undergraduates freely filled out the survey. Three scales were included in the survey: one for achievement goals, one for the metacognitive inventory, and one for mathematical modelling competency. Students majoring in mathematics took about forty minutes to respond to the questionnaires.

### Instruments

*Mathematical modelling competency test questionnaire.* The 22-item scale created by Haines and Crouch (2001) is the main instrument used in the literature to evaluate undergraduate mathematical modelling competency. This questionnaire assesses eight sub-dimensions of mathematical modelling competency from simplify assumptions to real and mathematical world connections. Each sub-dimension is represented by a set of questions. For example, one question asks students to consider the real-world problem (do not try to solve it!): What is the best size for bicycle wheels? Which one of the following clarifying questions most addresses the smoothness of the ride? A. Are the wheels connected to the pedals by a chain? B. How tall is the rider? C. Has the bicycle got gears? D. How high is the highest kerb that can be ridden up? E. Does terrain matter? This is a question about clarifying the goal dimension. These 22 questions span eight dimensions, ensuring a comprehensive evaluation of undergraduate mathematical modelling competency. This scale is well-respected, meeting the necessary requirements for validity and reliability, and has been widely used in mathematical modelling competency studies.

*Metacognition inventory.* Four aspects with five statements each make up the metacognitive inventory questionnaire, which was developed by O'Neil and Abedi (1996) and updated by Yildirim (2010) for use in evaluating mathematical modelling competency. Planning, self-checking, cognitive strategy, and awareness are the dimensions. The metacognitive inventory questionnaire has a 5-point scale (1= disagree, 5=strongly agree). For example, the five statements in the following are about planning dimension. 1.I am always aware of my own thinking. 2. I always double check my work. 3. I attempt to discover the main ideas in an exercise. 4. I try to understand the goals of an exercise before I attempt to solve it.5. I am aware of what problem-solving strategies to use and when to use them to solve an exercise.

*Achievement Goals Scale.* The 3×2 achievement goal model created by Elliot et al. (2011) serves as the foundation for the achievement goal questionnaire. Six categories make up this questionnaire, which are separated into performance goals (other-approach and other-avoidance goals) and mastery goals (task-approach, task-avoidance, self-approach, and self-avoidance goals). Each dimension has three objects. The questionnaire has eighteen items, each with a seven-point Likert-type scale that represents one of the six dimensions. The 3x2 achievement goal questionnaire uses a 7-point scale (1= strongly disagree, 7=strongly agree). For example, the three statements in the following are about task-approach dimension. 1.To get a lot of questions right on the exams in this class.2. To know the right answers to the questions on the exams in this class. 3. To answer a lot of questions correctly on the exams in this class.

**Data Analysis**

SPSS 27.0 software is used to assess data validity, reliability and related descriptive statistics. A typical tool used in reliability assessments is the Cronbach's alpha coefficient (Taber, 2018). This coefficient has a range of 0 to 1, and its interpretation is based on the following standards, like Table 1 shows. The Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) metric is used to assess validity, see Table 1. The requirements for univariate normality in a latent variable measurement model state that, at a significance level of 0.05, each item's skewness and kurtosis values must fall between -1.96 and 1.96 (Melton, 1995).

Table 1
Reliability and validity analysis criteria

| KMO Value | Evaluation | Cronbach's α | Evaluation |
|---|---|---|---|
| >0.8 | Great | >0.9 | Good |
| 0.8≥KMO≥0.7 | Good | 0.9≥α≥0.7 | Acceptable |
| 0.7>KMO≥0.6 | Acceptable | <0.7 | Poor |
| <0.6 | Poor | | |

Note. Source from (Sharma, 2016; Traymbak, Shukla & Dutta, 2024)

Confirmatory factor analysis (CFA) is performed using AMOS 28.0 to assess whether the dimensionality and factor-loading pattern found are appropriate for the Chinese context. The average variance extracted (AVE) should exceed 0.36. and composite reliability (CR) should also be greater than 0.6 (Fornell & Larcker, 1981). The standard error of each path coefficient should be small, and the t value of the path coefficient should be significant (usually the absolute value of the t value should be greater than 1.96, and the p value is less than 0.05), indicating that the path is statistically significant. A standardized estimate greater than 0.7 indicates that the observed variable has a strong explanatory power on the latent variable, and a standardized estimate between 0.5 and 0.7 indicates that the observed variable has a moderate explanatory power on the latent variable, which is generally considered acceptable (Schumacker & Lomax, 2004). At the same time, the hypothesis model is tested. The following criteria were used, like Tabe 2 shows.

Table 2
Model test index criteria

| Evaluation Indicators | Values | Evaluations |
|---|---|---|
| GFI | > 0.85 | Acceptable |
| TLI | > 0.85 | Acceptable |
| CFI | > 0.85 | Acceptable |
| IFI | > 0.85 | Acceptable |
| NFI | > 0.85 | Acceptable |
| AGFI | > 0.85 | Acceptable |
| RMSEA | < 0.08 | Acceptable |
| SRMR | < 0.08 | Acceptable |

Note. Source from (Aaron Benjamin Taylor, 2008)

Understanding the function of a mediator is essential before moving on to mediation analysis. An intervening variable, sometimes known as a mediator, modifies the effect of an independent variable on dependent variable (MacKinnon, 2017). Two distinct mediation scenarios are investigated in this study. First, full mediation happens when the independent variable (achievement goals) and the dependent variable (MMC) do not show any obvious direct correlation. When a direct relationship exists between the independent and dependent variables, however, partial mediation occurs. The AMOS 28.0 program was utilized to assess the relevance of indirect effects and ascertain the degree of mediator influence on the overall effect on the outcome variable.

## FINDINGS

### Analysis of Validity and Reliability

For MMC, achievement goals and metacognition, the Cronbach's α coefficients are 0.867, 0.928, and 0.937, correspondingly. The KMO values are 0.872, 0.837, and 0.844 respectively. Since each value satisfies the required standards, the reliability and validity coefficients are also considered satisfactory. Every variable measurement item satisfies the requirements with an absolute skewness of less than 0.5 and an absolute kurtosis of less than 1.3, all of which are compatible with a normal distribution.

### Analysis of Confirmatory Factors

*Confirmatory Factor Analysis of Achievement Goals*

The six achievement goal dimensions—task-approach, task-avoidance, self-approach, self-avoidance, other-approach, and other-avoidance—have a combined total of 18 elements. A satisfactory model fit is indicated by the standardized factor loadings, which range from 0.623 to 0.899 for the six dimensions. The six dimensions have respective AVE values of 0.501, 0.654, 0.535, 0.719, 0.702, and 0.716, all of which satisfy the standard value of larger than 0.36. The coefficient of determination for the fit indices is 0.061 for the root mean square error of approximation (RMSEA), 0.938 for the goodness of fit index (GFI), 0.912 for the adjusted goodness of fit index (AGFI), 0.944 for the normed fit index (NFI), 0.959 for the comparative fit index (CFI), and 0.959 for the incremental fit index (IFI). The model has passed the fit test since each of these indices satisfies the reference requirements.

*Confirmatory Factor Analysis of Metacognition*

A good model fit about metacognition is indicated by the first-order factors' standardized factor loadings, which vary from 0.563 to 0.785. The first-order factor AVE values, which range from 0.415 to 0.522, satisfy conventional criteria and show strong construct reliability for the variable. The fit indices display the following: the AGFI is 0.888, NFI is 0.913, CFI is 0.935, IFI is 0.936, RMSEA is 0.061 and the GFI is 0.912. The fact that each of these values satisfies the reference requirements means the model passes the goodness-of-fit test.

*Confirmatory Factor Analysis of Mathematical Modelling Competency*

For MMC, the standardized factor loadings for the eight dimensions range from 0.481 to 0.976, indicating a good model fit. The AVE values for the first order range from 0.402 to 0.592, meeting the standard value of greater than 0.36. The fit indices show that the RMSEA value is 0.044, the GFI value is 0.947, the AGFI value is 0.926, the NFI value is 0.909, the CFI value is 0.945, and the IFI value is 0.946. All these indices meet the reference standards, indicating that the model passes the fit test.

**Structural Equation Model Testing of Variables**

*Relationship Between Achievement Goals and Mathematical Modelling Competency*

Using Amos 28.0, a structural equation model was constructed with achievement goals as the independent variable and MMC as the dependent variable to verify the impact of achievement goals (AG) on undergraduates' mathematical modelling competency (MMC). The results are shown in Figure 2 and Table 3 and 4.

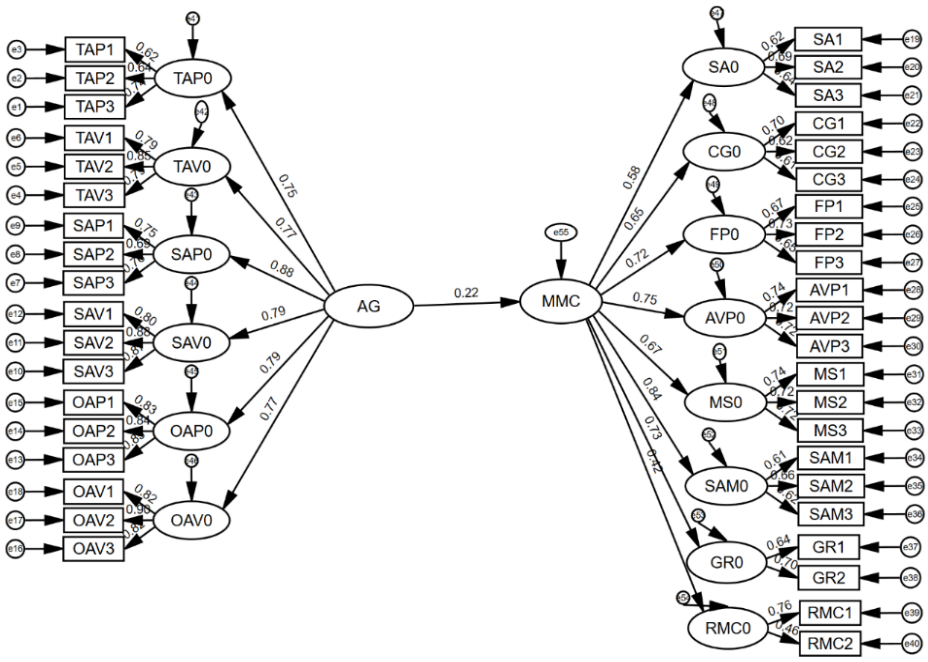


Figure 2
Structural equation model of achievement goals and MMC

Table 3
Significance Test Results of Direct Paths for Achievement Goals

| Pathway | Estimate | St. Est | S.E. | t Value | P |
|---|---|---|---|---|---|
| AG-->MMC | 0.071 | 0.218 | 0.016 | 4.304 | *** |
| AG-->MC | 0.306 | 0.438 | 0.04 | 7.688 | *** |
| MC-->MMC | 0.128 | 0.268 | 0.025 | 5.126 | *** |

Table 4
Fit indices of higher-order structural equation model

| Pathway | Chi-square/df | RMSEA | GFI | AGFI | CFI | NFI | TLI | SRMR |
|---|---|---|---|---|---|---|---|---|
| AG-->MMC | 2.002 | 0.038 | 0.907 | 0.895 | 0.936 | 0.881 | 0.931 | 0.0446 |
| AG-->MC | 2.917 | 0.053 | 0.869 | 0.852 | 0.913 | 0.874 | 0.907 | 0.0485 |
| MC-->MMC | 1.865 | 0.035 | 0.901 | 0.889 | 0.935 | 0.87 | 0.93 | 0.0444 |
| AG-->MC-->MMC | 1.915 | 0.036 | 0.863 | 0.852 | 0.917 | 0.841 | 0.913 | 0.0457 |

According to Table 3, the test results of the main effect structural model show that the t value is 4.304, which is greater than 1.96, and the p-value is less than 0.001, passing the significance test. The path coefficient is greater than zero, indicating a significant positive effect of achievement goals on college students' mathematical modelling competency. As shown in Table 4, the ratio of chi-square to degrees of freedom is less than 3, and the fit indices RMSEA, GFI, AGFI, NFI, TLI, and SRMR all meet the criteria, indicating a good fit of the model, this result validates H1.

*Relationship between Achievement Goals and Metacognition*

Using Amos 28.0, a structural equation model was constructed with achievement goals as the independent variable and metacognition as the dependent variable to examine the impact of achievement goals (AG) on metacognition (MC). The results are shown in Figure 3 and Tables 3 and 4.

According to Table 3, the test results of the structural equation model indicate that the t value is 7.688, which is greater than 1.96, and the p-value is less than 0.001, passing the significance test. The path coefficient is greater than zero, indicating a significant positive effect of achievement goals on metacognition.

As shown in Table 4, the fit indices RMSEA, GFI, AGFI, NFI, TLI, and SRMR all meet the criteria, indicating a good fit of the model, this result validates H2.

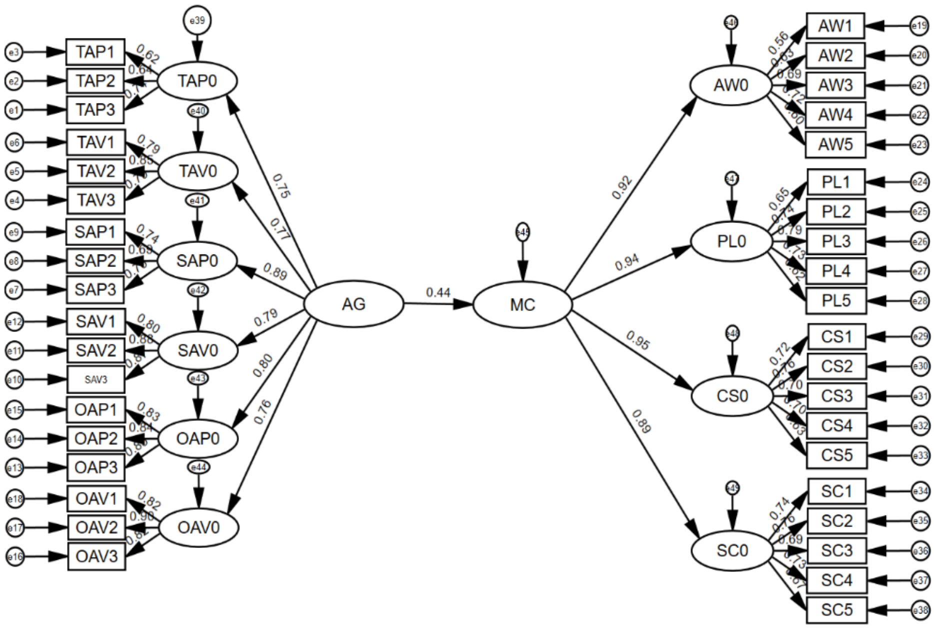


Figure 3
Structural equation model of achievement goals and metacognition

*Relationship between Metacognition and Mathematical Modelling Competency*

Using Amos 28.0 to construct a structural equation model, with metacognition as the independent variable and mathematical modelling competency as the dependent variable, validate the influence of metacognition on MMC. The results are shown in Figures 4 and Tables 3 and 4.

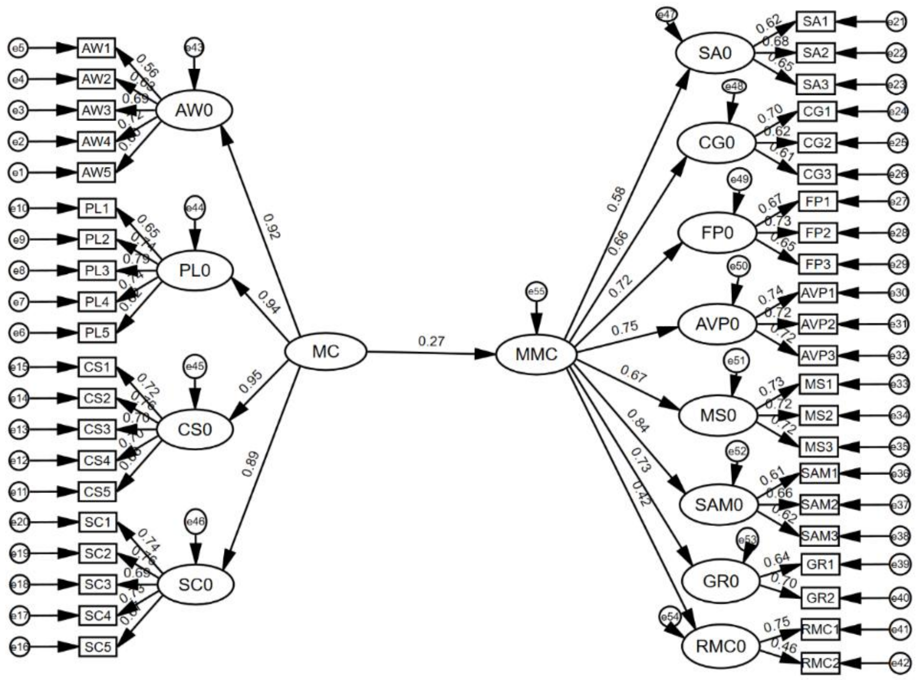

Figure 4
Structural equation model of metacognition and MMC

According to Table 3, based on the examination results of the structural equation model, the C.R. value is 5.126, greater than 1.96, with a p-value less than 0.001, passing the significance test. The path coefficient is greater than zero, indicating a significant positive effect of metacognition on mathematical odelling competency. According to Table 4, the chi-square/degrees of freedom ratio is less than 3, and the fit indices RMSEA, GFI, AGFI, NFI, TLI, and SRMR all meet the judgment criteria, indicating a good fit of the model, this result validates H3.

*Test the Mediating Role of Metacognition*

Using Amos 28.0 to construct a one-factor mediation structural equation model, with achievement goals as the independent variable (exogenous variable), metacognition as the mediating variable, and mathematical modelling competency as the dependent variable (endogenous variable), the mediating role of metacognition in the influence of achievement goals on MMC was validated. The results are shown in Figure 5 and Tables 4 and 5.

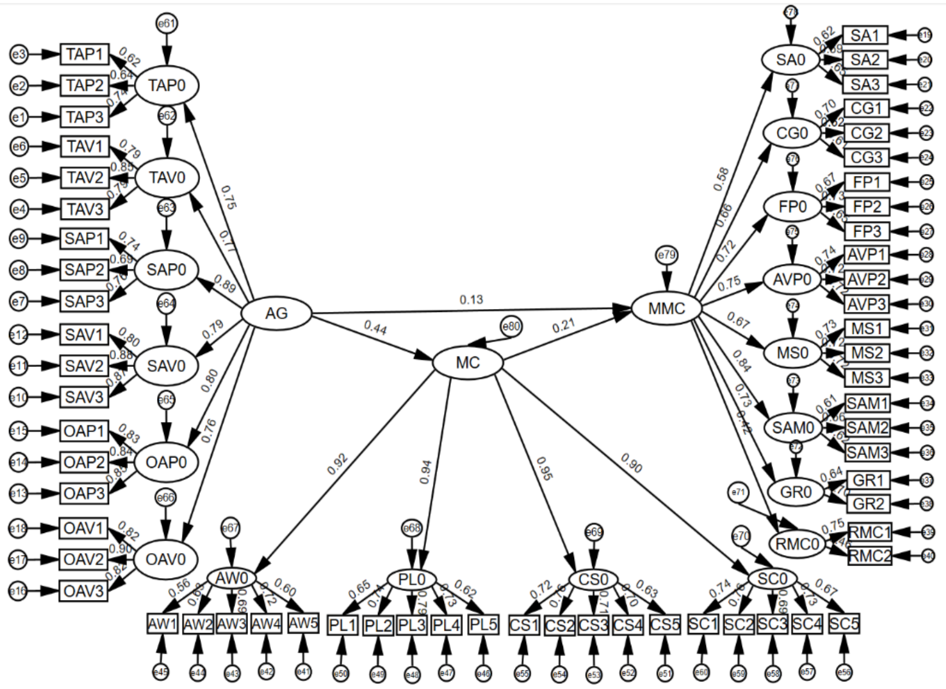


Figure 5
Structural equation model of the mediating effect of metacognition

As shown in Figure 5, a metacognition factor mediation model was constructed. Considering the staged literature research results on mediation behavior, an empirical measurement method was selected. This study used the bootstrap method (2000 times) to test the mediation effect. The non-standardized coefficient value of the indirect effect is 0.031, the non-standard error is 0.01, and the significance level of the indirect effect is 0.031/0.01=3.1>1.96, demonstrating the presence of an indirect effect.

Table 5
Examination results of the metacognition mediation effect model

| Pathway | Point Estimate | Product of Coefficients | | Bootstrapping | | | |
|---|---|---|---|---|---|---|---|
| | | | | Bias-correct 95% CI | | Percentile 95% CI | |
| | | SE | Z | Lower | Upper | Lower | Upper |
| *Total Effects* | | | | | | | |
| AG--> MMC | 0.071 | 0.016 | 4.438 | 0.042 | 0.107 | 0.042 | 0.107 |
| *Indirect Effects* | | | | | | | |
| AG--> MMC | 0.031 | 0.009 | 3.444 | 0.015 | 0.052 | 0.014 | 0.051 |
| *Direct Effects* | | | | | | | |
| AG--> MMC | 0.041 | 0.017 | 2.35 | 0.008 | 0.076 | 0.008 | 0.077 |

As shown in Table 5, the value of the indirect effect ranges from 0.015 to 0.053, with the interval excluding 0, indicating the presence of a mediation effect. It is a partial mediation model, this result validates H4.

**DISCUSSIONS AND CONCLUSIONS**

This study investigated the relationship between metacognition and achievement goals and their impact on mathematical modelling competency of mathematics majors, especially examined the mediating effect of metacognition on achievement goals and mathematical modelling competency.

The influence of achievement goals on mathematical modelling competency is examined. The findings align with prior research (Elliot & McGregor, 2011; English & Gainsburg, 2015). Using the Amos 28.0 structural equation model, the results provide robust evidence that achievement goals play a significant positive role in enhancing undergraduate mathematical modelling competency. The findings suggest that students who set clear and specific goals in their mathematical learning tend to develop stronger modelling abilities, enabling them to approach complex problems more effectively. By guiding students to set clear goals in the problem-solving process, students who set achievement goals are more likely to maintain a positive attitude and high level of participation in challenging tasks, resulting in better performance in mathematical modelling tasks.

Based on the results of the Amos 28.0 structural equation model, metacognition has a positive influence on mathematical modelling competency. The findings align with prior research (Azevedo et al., 2017; Hidayat, Zulnaidi & Zamri, 2018) are consistent. Undergraduates who actively engage in metacognitive practices, such as self-reflection, planning, and monitoring their problem-solving processes, tend to perform better in mathematical modelling tasks. These results suggest that metacognition is a critical factor in students' ability to tackle complex mathematical problems, supporting the development of stronger modelling skills. Moreover, the study highlighted the mediating role of metacognition between achievement goals and mathematical modelling competency, further underscoring its importance. By improving their awareness of their own cognitive processes, students can better apply their mathematical knowledge and skills to real-world problems, leading to more effective and accurate modelling outcomes.

Metacognition modifies undergraduate achievement goals, which in turn affects how well they can model mathematics. This shows that students might further improve their mathematical modelling competency by better formulating and executing achievement goals connected to mathematical modelling by cultivating and developing their metacognitive skills. As an illustration, awareness, one of the fundamental components of metacognition, aids students in appreciating the significance of their learning objectives and goals (Salam et al., 2020). Students may be more motivated to develop and pursue mathematical modelling achievement goals, such as honing their modelling techniques or working through challenging problems, because of their increased awareness. Students who possess planning skills are better equipped to create plans and methods to accomplish these objectives (Naufal et al., 2021), which helps them advance toward developing mathematical modelling competency. Furthermore, metacognitive abilities such as self-monitoring and cognitive techniques offer significant assistance to students as they work on their achievement goals. Undergraduates can more effectively handle difficulties in the mathematical modelling process and generate solutions when applying cognitive strategies effectively. Through self-monitoring, students can more effectively meet their learning objectives by promptly recognizing and fixing mistakes made during the learning process. Consequently, a deeper understanding of the relationship between achievement goals and mathematical modelling competency is provided by the mediating role of metacognition. Students who develop and hone their metacognitive skills are better able to formulate and carry out achievement goals, which in turn enhances their mathematical modelling competency.

## LIMITATIONS

This study's definition of mathematical modelling competency is quite limited, with a primary emphasis on the atomistic viewpoint. In the future, we need to conduct in-depth and detailed research on the accurate expression of mathematical modelling competencies and the division of dimensions. Subsequent studies ought to investigate the impact of achievement goals and metacognition in mathematical modelling as an educational instrument. Further research is warranted to examine the effects of achievement goal subdimensions on mathematical modelling competency and metacognition, as well as the connections between metacognitive and achievement goal subdimensions.

## IMPLICATIONS

The findings of this study offer several significant implications for mathematics education, particularly in developing students' mathematical modelling competency. The positive influence of achievement goals on mathematical modelling competency highlights the importance of fostering a goal-oriented learning environment. Educators should encourage students to set both short-term and long-term learning goals that are specific and challenging. This suggests that embedding goal-setting practices within the curriculum could serve as an effective strategy for improving students' mathematical competencies. The study confirms the substantial positive effect of metacognition on mathematical modelling competency, underscoring the need for instructional strategies that promote metacognitive awareness. Teachers should integrate opportunities for students to reflect on their own thinking processes, plan their problem-solving approaches, and monitor their progress.

Moreover, the identification of metacognition as a mediator between achievement goals and mathematical modelling competency suggests that combining metacognitive strategies with goal-setting practices can significantly amplify the positive effects on students' mathematical modelling competency. This means that educational programs should focus on linking goal-directed behaviours with metacognitive reflections, enabling students to better manage their cognitive resources when engaging with complex mathematical problems.

In conclusion, integrating achievement goals and metacognitive practices into mathematics education holds great potential for improving students' mathematical modelling competency, making them better equipped to apply their mathematical knowledge in real-world contexts.

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