Research article

Meta-cognitive behaviour and mathematical modelling competency: mediating effect of performance goals

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ABSTRACT

Guided by a model promoted by Biccard and Wessels (2011) and empirical evidence, this work aims to examine a model that includes meta-cognitive behaviour and mathematical modelling competency with the indirect effects of two performance goal sub-constructs, namely, other-approach and other-avoidance goals. The study investigates the correlation between meta-cognitive behaviour and performance goals that may affect mathematical modelling competency. A total of 538 mathematics education programme students (89.8% female and 10.2% male) in Indonesia are considered. A correlational study is performed to examine the level of the link amongst mathematical modelling competency, performance goals and meta-cognitive behaviour. Results show that meta-cognitive behaviour positively affects mathematical modelling competency, but no significant direct relationship is observed between performance goals and mathematical modelling competency. Furthermore, other-approach and other-avoidance goals are significant mediators between meta-cognitive behaviour and mathematical modelling competency. We conclude that meta-cognitive behaviour positively influences the mathematical modelling competency of students, which is unaffected by other-approach and other-avoidance goals.

1. Introduction

Engaging pupils in realistic problem solving, including complicated systems in an interdisciplinary setting, is considered defiance in the 21st century (English, 2009). A promising way is to encourage mathematical modelling competency, which refers to loops of model development, assessment and refinement (Blomhoej and Jensen, 2003). According to Gainsburg (2006), pupils are required to construct, describe, explain, manipulate and predict complicated systems. Mathematical modelling competency is the ideal approach for developing such competencies. On the contrary, English et al. (2008) indicated that conventional designs of problem solving are free of the construction of fundamental mathematical insights, understanding and processes and do not provide pupils a chance to investigate complicated real-world data. Modelling in mathematical instruction has received robust support from several educational researchers (Niss et al., 2007). The general consensus is that the modelling process is difficult (Kartal et al., 2016; Wijaya et al., 2014; Yew & Akmar, 2016). In particular, the sub-construct of modelling involves transformation from a real context to a mathematical context. Vorhölter (2019) found that pupils encounter problems in constructing a model and recognising meaningful assumptions. Another researcher discovered that

low-achievement pupils may already be perplexed at the first stage of the modelling cycle and are thus unable to proceed with other procedural knowledge when resolving a context-based problem (Wijaya et al., 2014). These students lack experience related to real-world tasks. Educators must assist these pupils by understanding their challenges and mathematical skills in problem solving. Notably, prospective teachers in mathematics education also admit that they struggle in the modelling cycle (Anhalt et al., 2018; Ng, 2013; Widjaja, 2013).

Despite the huge challenge of teaching mathematical modelling, limited research has been conducted on why mathematical modelling competency is difficult to achieve and how certain factors influence it. Various studies have been conducted to understand the factors that might affect the mathematical modelling competency of students (Frejd and Ärlebäck, 2011; Mischo and Maaß, 2012; Schukajlow et al., 2015). Previous researchers have suggested that other potential factors, such as goal orientation (Topcu and Leana-Tascilar, 2016) and meta-cognitive behaviour (Galbraith, 2017), affect pupils. The two factors are part of what defines mathematical modelling competency (Biccard and Wessels, 2011), which means that they are no longer assumed to be positive side effects but significant constituents of mathematical modelling competency. Zimmerman and Campillo (2003) stated that merely possessing

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knowledge about solving a complex problem is insufficient; robust motivation and private resourcefulness are also required to complete a challenge. To our knowledge, the effects of meta-cognitive behaviour and performance goals on the mathematical modelling competency of students have not been tested yet.

Only few studies have documented the relationship amongst these variables for the achievement of mathematical modelling competency. We broaden previous mathematical modelling competency discussions by criticising these relationships in contextual problems. This work explores the correlation between meta-cognitive behaviour and performance goals that might affect mathematical modelling competency in higher education. The research also focuses on the mediating effects of the correlation between meta-cognitive behaviour and mathematical modelling competency, with the indirect effects of two performance goal sub-constructs, namely, other-approach and other-avoidance goals.

2. Theoretical framework

The review aims to understand the literature related to realistic mathematics education (RME) and includes a few of the latest studies. The relationship amongst mathematical modelling competency, performance goals and metacognition is discussed.

2.1. Realistic mathematics education

Changes have been achieved from the didactical usage of fixed processes to a viewpoint of modelling as dynamic models. The transformations in theoretical orientation are connected to the use of an appropriate instructional approach, i.e. domain-specific instruction theory for RME in this case (Gravemeijer, 2002). The basic principle of RME theory is that mathematics is a human activity (Freudenthal, 1968, 1991). RME has much in common with socio-constructivist-based mathematics education (Cobb et al., 2008; Gravemeijer and Terwel, 2000). One of the similarities between RME and socio-constructivist mathematics education is that students are given an opportunity to share their experiences with counterparts. The instructional sequences in RME complement the constructivist view on mathematical lessons (Cobb et al., 2008). For example, RME's basic principle defines mathematics as a human activity (Freudenthal, 1968, 1991), and this action must result in mathematics as a product (Gravemeijer and Terwel, 2000). In terms of the modelling process, RME and constructivism represent a bottom–up dynamic approach (Gravemeijer and Stephan, 2002).

The main point in RME theory is that the modelling process is defined as the mathematisation of reality. The result of mathematisation is a process of mathematisation and not a product (Lange, 1987). Lange (1987) further explained that the aim is for students to be able to implement non-mathematical decisions, comparisons or evaluations by employing mathematics as a tool rather than by generating a numerical answer. Therefore, mathematising or mathematisation (Niss, 2015) is also known as modelling. However, because modelling is considered a competency, the definition of mathematical modelling competency that is greatly linked to the modelling process has also been emphasised in modelling research (Ludwig and Reit, 2013; Mehraein and Gatabi, 2014; Yilmaz and Tekin-Dede, 2016). However, the meaning of mathematical modelling competency has not been clarified in mathematics because of different views. Although it has diverse meanings, Stillman et al. (2007) stated that many agree that modelling involves formulation, solution, interpretation and evaluation processes.

2.2. Mathematical modelling competency

A standard framework for mathematical modelling is yet to be agreed upon. Modelling has been used extensively in literature (e.g. Blomhoej and Jensen, 2003; Blum and Leiß, 2005; Ferri, 2006; Galbraith et al., 2010; Galbraith and Stillman, 2006; Kaiser & Sriraman, 2006; Lange, 2006; Lesh and Doerr, 2003; Shahbari and Peled, 2017; Sokolowski,

2015; Verschaffel et al., 2002; Zbiek and Conner, 2006). Processes differ from each other because of distinctive perspectives (Blomhøj, 2009; Kaiser and Sriraman, 2006), but they usually offer a visual display of phases. Modelling processes are classified into six perspectives, namely, realistic, contextual, educational, socio-critical, epistemological or theoretical and meta-perspective (Haines and Crouch, 2001). The current study falls under the educational perspective on mathematical modelling. Blomhøj (2009) stated that the discussion about models, modelling, the modelling cycle, modelling competency and applications is a prominent aspect in research under this perspective.

Mathematical modelling is taught from two main perspectives, that is, modelling as a vehicle and modelling as content (Galbraith, 2007, 2012; Julie, 2002). The rationale for modelling as a vehicle concentrates on the ways in which modelling has been used to introduce other curricular materials and associated priorities or to allow students to learn (Galbraith, 2012). Modelling is a form of competence to simplify the development of mathematical understanding (Freeman, 2014). According to Julie (2002), modelling is a paradigm that dominates model construction activity. This view aims not only to assist students in obtaining strong mathematical knowledge on certain topics but also to encourage them to see the relationship of mathematics with the real world. Still under this view, emergent modelling is one of the approaches to encourage modelling activity in mathematical lessons (Galbraith, 2012). The concept of emergent models is a dominant design heuristic in RME (Gravemeijer and Doorman, 1999) for constructing mathematical concepts and understanding (Galbraith, 2012).

The primary aim of the perspective of modelling as content is to improve modelling competency, such as understanding and simplifying problems, organising problems, mathematisation, mathematical work, interpreting solutions, validating solutions and presenting solutions. Numerous empirical studies have examined mathematical modelling competency. Several of them have found that students encounter difficulties in simplifying, mathematising (Dede, 2016; Delice and Kertil, 2015; Eraslan and Kant, 2015; Shahbari and Peled, 2017), interpreting and validating problems (Dede, 2016). Moreover, using modelling-based text can enhance students' modelling competencies and allows them to apply scientific information to the development of conceptual knowledge (Jong et al., 2015). Although modelling as vehicle and as a content have different principles, both perspectives agree that task design is a central point.

2.3. Performance goals

Researchers agree that the primary idea of achievement goal theory has two emphases, namely, mastery and performance goals (Dweck, 1986; Nicholls, 1984). Mastery goals (adaptive) are reflected by defiance search and great, effective perseverance in the face of obstacles, whereas performance goals (maladaptive) are characterised by defiance avoidance and small persistence in the face of difficulty. The current research focuses only on performance goals because limited research has been conducted on why and how performance goals (i.e. other-approach and other-avoidance goals) are connected to complex problems, such as mathematical modelling tasks. The application of performance goals to mathematical lessons has been assumed to result in sensitivity to a 'powerless' scheme of responses in achievement settings (Elliot and Church, 1997). These reactions include a preference for simple or complex problems, the retraction of effort in the face of default and the mitigation of task enjoyment. Pupils who exhibit performance goal orientation are inclined to have negative feelings (e.g. anxiety) and negative self-cognitions when facing barriers. The performance goal model is differentiated into approach and avoidance (Elliot and McGregor, 2001; Elliot, 1999). Performance-approach and performance-avoidance goals concentrate on the achievement of other-based capability and incapability, respectively. Performance approach and avoidance goals refer to other-approach and other-avoidance goals (Elliot et al., 2011). Other-approach goals are

defined as the achievement of interpersonal terms (approaching success) (e.g. 'make better than the other counterpart'), and other-avoidance goals are defined as the achievement of interpersonal terms (avoiding failure) (e.g. 'evade making worse than the other counterpart'). According to Elliot (2005), other-approach goals require an approach inclination and an appetitive shape of motivation.

Performance goals predict the surface strategy (Matos et al., 2017) and resource management strategies (Vrugt and Oort, 2008). The interrelationship between performance goals and mathematical modelling competency has been established by numerous studies in other fields. Although performance goals (other-based goals) can foresee positive learning results (Liu et al., 2017), this kind of goals has a low relationship with the cumulative grade point average (Mirzaei et al., 2012). Meanwhile, Mascret et al. (2017) suggested that other-approach goals are positively connected or unconnected to intrinsic interest, whereas other-avoidance goals are negatively connected or unconnected to intrinsic interest. Subsequent evidence stems from the negative interrelationship between other-approach goals and exam achievement (Stoeber et al., 2015) and between other-avoidance goal structures and achievement (Matos et al., 2017). Previous research has also confirmed that students with other-approach goals need to seek additional help (Yang et al., 2016). Further evidence can be obtained from the positive relationship between performance approach and avoidance goals and the self-oriented perfectionism factor (Magno et al., 2017). Specifically, in the mathematical field, students who utilise performance goals do not accomplish certain problem solving indicators, such as planning, executing the plan and reflecting to identify a solution (Maretasani et al., 2016). Thus, on the basis of previous studies, we hypothesise that student performance goals, which reflect other-approach and other-avoidance goals, are negatively connected to mathematical modelling competency. To the best of our knowledge, the relationship between performance goals and modelling competency has not been tested yet. Only a few studies have illustrated goal orientation as a mediator in academic achievement (Chen, 2015; Diseth and Kobbeltvedt, 2010; Magno et al., 2017).

Limited evidence has corroborated that other-approach and other-avoidance goals are mediators. Although prior studies have revealed that performance-avoidance goals mediate relations between competence beliefs and anxiety with a small proportion of variance, performance-approach goals are not considered mediating effects in research (Putwain and Symes, 2012). Elliot and Church (2003) found that performance-avoidance goals partially mediate the negative correlation between self-handicapping and exam performance and GPA. Likewise, certain research has shown that performance goals serve as mediators between the impacts of perfectionism on procrastination (Magno et al., 2017) and between time pressure and performance (Beck and Schmidt, 2013). Zimmerman and Campillo (2003) indicated that learners should not merely have adequate knowledge, especially on resolving a complicated task, but should also possess robust motivation (goals) and private resource to conduct defiance. Given that students with performance goals need to seek additional help (Yang et al., 2016) in group activities, the presence of performance goals as a mediator is appropriate for solving complicated tasks. Houston (2007) reported that modelling is usually perceived as a group activity. Therefore, the current research proposes that performance goals can serve as a mediator that explains the vague correlation of the components of metacognition and modelling competency. Meta-cognitive behaviour, driven by psychological necessity and cognitive concepts, is related to the desire to perform better than others in order to solve complex problems. We hypothesise that meta-cognitive behaviour is linked to performance-approach goals, which are in turn related to mathematical modelling competency.

2.4. Metacognition

Metacognition involves psychological and cognitive concepts (Papaleontiou-Louca, 2008) and is defined as the knowledge or activity

of people about their own cognitive processes and outcomes or something connected to them (Flavell, 1976). According to Flavell's (1976) model, metacognition is indicated by four major aspects, namely, metacognitive knowledge, experiences, goals and actions (or approaches). Metacognitive knowledge contains knowledge or belief factors (i.e. person, task and strategy) that serve and intercommunicate to affect the course and result of cognitive enterprises. In relation to modelling competency, Stillman (2011) provided examples of related factors in metacognitive knowledge. As a modeller, the person factor can be illustrated with the awareness of difficulty in easily formulating plausible estimates. The task factor pertains to the awareness of task characteristics that affect the task solution, and the strategy factor refers to the awareness of their effectiveness when used in the past. However, metacognitive knowledge on teaching processes might be right or wrong, and this self-knowledge is usually invulnerable to transformation (Veenman et al., 2006).

Metacognition is categorised as high-order thinking (Lesh and Zawojewski, 2007) and entails an active supervisor over the cognitive processes involved in the process of learning (Livingston, 2003). Metacognition is the most important approach related to mathematics accomplishment (Bonnett et al., 2016; Callan et al., 2016; Hidayat et al., 2018a; Hidayat et al., 2018b; Özcan, 2016; Tzohar-Rozen and Kramarski, 2014; Zhao et al., 2019) and problem solving skills (Shilo and Kramarski, 2019; Yusnaeni and Corebima, 2017). Several studies have emphasised the importance of meta-cognitive behaviour in increasing mathematical modelling competency (Hidiroğlu and Bukova-Güzel, 2016; Yildirim, 2010). For example, metacognition affects the modelling strategy development of pupils when the impacts of metacognitive components are considered (i.e. awareness, planning, cognitive strategy and self-checking) (Yildirim, 2010). Learners who have improved self-checking abilities exhibit increased modelling competency growth. Cognitive strategy and planning abilities are also mediators of modelling competency development. After several experiences with modelling, learners with escalated competencies in these two metacognitive components demonstrate improved modelling skills. In the study of Vorhölter (2019), the learners from the metacognition treatment group for modelling felt that they used strategies for evaluation more frequently. However, cognitive and metacognitive activities did not occur sequentially in the learning process. Instead, they were simultaneously produced and linked in the modelling process (Hidiroğlu and Bukova-Güzel, 2016).

2.5. Research question

The three principal research questions in the current study are as follows:

1. Do meta-cognitive behaviours directly influence mathematical modelling competency?
2. Do performance goals directly influence mathematical modelling competency?
3. Do performance goals exert a mediating effect on meta-cognitive behaviour and mathematical modelling competency?

3. Method

3.1. Procedure and participants

The present work uses correlational research to explore and gauge the level of relationship amongst performance goals, metacognition, and mathematical modelling competency (Codd, 1970). The relationships amongst performance goal, metacognition and mathematical modelling competency were measured via structural equation modelling (SEM) analysis (Byrne, 2012). A priori model that integrates variables was constructed based on theories and previous studies (Figure 1). Three main variables, namely, performance goal,
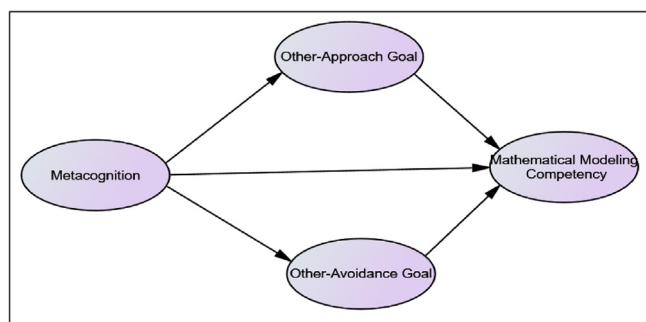
Figure 1. Previous model.

metacognition and mathematical modelling competency, were used, and the interrelationships between these constructs are revealed by the straight arrows in Figure 1. The model that combines these constructs has not been tested in prior literature, and the fit of the current model was assessed using SEM.

The population in the present research comprised 538 students of a mathematics education programme enrolled in Bachelor of Education (Mathematics) in Riau Province, Indonesia. The first consent letter from Universiti Malaya was sent to the Department of Investment and Integrated One Stop Services and the agency, which in turn sent this consent letter together with their own approval letter to three research locations. The research was approved by the Department of Investment and Integrated One Stop Services in Indonesia. Informed agreement was obtained from all respondents involved in the current research. Then, we distributed survey forms to participating universities within a two-month period. The population consisted of public and private universities in four regions with homogeneous characteristics, such as gender and socioeconomic status. The population was selected because the students take a mathematics course, which enables them to have common modelling experiences. We used cluster random sampling because the current research selected the sample according to groups rather than individuals (Fraenkel and Wallen, 2009). Given the difficulty of selecting a random sample of individuals, we randomly chose three universities, and all learners in a class participated in the study. Fraenkel and Wallen (2009) indicated that cluster random sampling can be employed if selecting a random sample of persons is difficult. In the end, 538 mathematics education programme students (89.8% female; 10.2% male) in Indonesia participated in the research.

3.2. Data collection tools

3.2.1. Mathematical modelling test

We used the mathematical modelling test with multiple-choice questions from Haines and Crouch (2001). The multiple-choice design allows for a robust focusing of ideas within a reasonable timescale (Haines and Crouch, 2001). We measured mathematical modelling competency by including the following items: 'simplify assumptions regarding the real-world task' (three items), 'clarify the goal of the real model' (three items), 'formulate a proper task' (three items), 'assign variables, parameters, and constants in a model on the basis of sound understanding of model and situation' (three items), 'formulate pertinent mathematical expressions representing the problem addressed' (three items), 'choose a model' (three items), 'interpret' (two items) and 'relate the mathematical solution to the real-world setting' (two items). A total of 22 items were used in the mathematical modelling test. Students with true responses were awarded 2 points, those with partially true responses were awarded 1 point and those with incorrect responses were awarded 0 points. We only utilised instruments from the work of Haines and Crouch (2001) because they covered complex dimensions of

mathematical modelling competency. One of the sample items of the eight sub-constructs of mathematical modelling competency asked the participants to consider the following real-world problem. '*A bus stop position has to be placed along a road on a new bus route. A covered shelter will be provided. Where should the stop be placed so that the greatest number of people will be encouraged to use the service? The bus company wants people to use the service but cannot lay on buses on demand*'. Which of the following assumptions do you consider the least important in formulating a simple mathematical model? (a) assume that just one bus shelter will be erected; (b) assume that the road is straight; (c) assume that the weather is twice as likely to be dry as it is to be wet; (d) assume that the bus runs to a half-hourly timetable; and (e) assume that customers will not walk great distances to catch a bus.

The present study involves two kinds of validity: content and construct validity. To confirm content validity, the researcher did not eliminate any item for each instrument. The instrument was also reviewed by many experts from several colleges. It was evaluated by a team of two mathematics experts (Kane, 2001) from Universitas Syiah Kuala (Unsyiah) and University of Malaya (UM). For metacognition and achievement goal instruments, the items were reviewed by a team of two psychology education experts from Universitas Gadjah Mada (UGM) and UM. Content validity also includes the wording and format of the items on a scale that conform to the construct of interest. In addition, an item response analysis was performed to indicate the discrimination and difficulty indices (Ariffin, 2008; Hambleton et al., 1991). The most common measurement models used for adaptive tests were within the framework of item response theory (IRT).

IRT generally defines a probabilistic relationship that associates item and test taker traits to the possibility of endorsing each of the response categories for that item. Given different IRT models, the three-parameter logistic model (3PL) was adopted here because it includes difficulty (b), discrimination (a) and randomness (c) or guessing parameters (Hambleton et al., 1991). An item's difficulty is the index of students answering correctly (Ariffin, 2008). Ariffin (2008) defined the discrimination index as a value that shows whether an item can distinguish between low- and high-performance students. Items are acceptable when they can distinguish two groups of students. The discrimination and difficulty indices for all questions, including correct answer, partial credit and wrong answer, were calculated with the Winsteps software. The item difficulty score ranged from +0.50 to −1.00 logits as determined using the Rasch model. It exceeds the acceptable score range of +3.00 to −3.00 logits and is assumed to be good (Linacre, 1994). Nineteen items are at the medium level, and three items are at the easy level. The discrimination indices of each question in the mathematical modelling test were from 24.55% to 57.27%, indicating that items 2, 13 and 7 had fairly good, good and very good discrimination indices, respectively. Moreover, using the binomial probability theorem, the probability to conjecture 10 correct responses was deduced to be approximately 0.0045 (Lingefjärd & Holmquist, 2005). Therefore, the questions for testing the students' mathematical modelling competency were retained in the actual study. Moreover, the measurement model of mathematical modelling competency was provided. The reliability score of the mathematical modelling test was good (0.82) (Tavakol and Dennick, 2011). Therefore, in the current research, each mathematical modelling competency item was retained for use in testing the students.

In addition, confirmatory factor analysis (CFA) was applied to determine the construct validity of the instrument, which also meant identifying any underlying association between the items in the scale. The composite reliability (CR) values of the mathematical modelling competency components ranged from 0.69 to 0.78 and surpassed the 0.6 desired standard. This finding indicates high internal consistency. The average variance extracted (AVE) of the eight latent constructs ranged from 0.50 to 0.63 and surpassed the 0.5 desired standard, demonstrating that the current research presents acceptable discriminant validity. Therefore, each mathematical modelling competency item in this research was retained for use in testing the students.

3.2.2. 3 × 2 achievement goal questionnaire

The instrument was adopted from Elliot et al. (2011) and involves six sub-constructs classified into mastery goals (i.e. task approach, task avoidance, self-approach and self-avoidance) and performance goals (i.e. other-approach and other-avoidance goals). This instrument has been tested for the Indonesian setting (Hidayat et al., 2018c). However, the current research only measured performance goals, that is, other-approach and other-avoidance goals. The questionnaire consists of six questions reflecting the two sub-constructs. A seven-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree) was used to measure the 3 × 2 achievement goal questionnaire (Gillet et al., 2015). The items of the other-approach and other-avoidance goals included the following: 'to do well compared with others in the class on the exams' and 'to avoid doing poorly in comparison with others on the exams in this class'. The reliability scores of certain scales surpassed the 0.70 desired standard (other-approach goal, $\alpha = 0.90$; other-avoidance goal, $\alpha = 0.88$). Meanwhile, all CR scores of the performance goal sub-construct ranged from 0.91 to 0.95 and surpassed the 0.6 desired standard, indicating high internal consistency. The AVE of the two latent constructs also ranged from 0.74 to 0.91 and surpassed the 0.5 desired standard, demonstrating that this research presents good discriminant validity.

3.2.3. Meta-cognitive inventory questionnaire

O'Neil and Abedi (1996) originally developed the meta-cognitive inventory that Yildirim (2010) modified and used in mathematical modelling competency. The instrument involves four sub-constructs comprising 20 statements, with 5 statements per sub-dimension. A five-point Likert-type scale with responses of strongly disagree (1), disagree (2), uncertain (3), agree (4) and strongly agree (5) was used to measure meta-cognitive behaviour. Sample items of cognitive strategy, awareness, self-checking and planning included the following: 'I use multiple solution methods to solve an exercise', 'I was aware of which thinking technique or strategy to use and when to use it', 'If I realise an error whilst working on an exercise, I always correct it' and 'I choose and organise pertinent information before starting to resolve an exercise'. The Cronbach's alpha of the four metacognition sub-dimensions exceeded the $\alpha > 0.70$ minimum common cut-off (awareness, $\alpha = 0.83$; cognitive strategy $\alpha = 0.85$; planning $\alpha = 0.84$; self-checking, $\alpha = 0.83$). The CR scores of the metacognition sub-dimension ranged from 0.83 to 0.85 and surpassed the 0.6 desired standard, indicating high internal consistency. The AVE of the four latent constructs ranged from 0.50 to 0.54 and surpassed the desired standard of 0.5, demonstrating that this research presents acceptable discriminant validity.

3.3. Methods for analysing data

The current research considered many data screening-related issues. Outliers were identified through a boxplot for each sub-dimension. The kurtosis and skewness scores of each item [(−1.96) – (+1.96)] at the 0.05 significance level (Hair et al., 2010) were used to test normality (Hair et al., 2010). Correlations less than 0.90 were regarded as free of multicollinearity (Kline, 2005).

CFA procedures were implemented using AMOS 18.0. According to Awang (2012), goodness of fit is evaluated through the chi-square (χ^2) (P > 0.05), the comparative fit index (CFI >0.90), the Tucker–Lewis index (TLI> 0.90) and the root mean-square error of approximation (RMSEA <0.08). The Cronbach's alpha coefficients, CR, AVE and split-half correlations were computed to determine the reliability of the questionnaire. The alpha scores in the current research were not expected to be comparatively high. According to Hair et al. (2010), alpha scores in the range of 0.60–0.70 in exploratory research are satisfactory. CR should not be less than 0.60, and AVE should not be less than 0.50 (Awang, 2012). The mediating effects were examined through a bootstrapping analysis in the current study to determine the extent to which a mediator influenced the total effect of the endogenous construct.

3.3.1. Initiatory analysis: instrument validity and reliability

A preliminary analysis considers many data screening-related issues, such as dealing with missing values, normality and multicollinearity. This study has no missing data. In the study of Kline (2005), univariate normality and multivariate normality were fulfilled prior to implementing the analysis with AMOS version 8.0. The kurtosis and skewness scores of each item [(−1.96) – (+1.96)] at the 0.05 significance level (Hair et al., 2010) were used to test normality in the present study. The outputs of the preliminary analysis for the measures of mathematical modelling competency, performance goals and metacognition achieved univariate normality (the skewness and kurtosis values were from −1.109 to 1.827).

4. Results

4.1. Correlations between constructs

The results indicated a significant correlation amongst mathematical modelling competency, performance goals and metacognition (Table 1). Mathematical modelling competency was significantly correlated with metacognition ($r = .537$), other-approach goal ($r = .379$) and other-avoidance goal ($r = .313$). Metacognition was significantly correlated with other-approach goal ($r = .509$) and other-avoidance goal ($r = .485$). In addition, other-approach goal was significantly correlated with other-avoidance goal ($r = .607$). Therefore, the variables had discriminant validity because the correlation matrix with correlations did not exceed 0.90 (Kline, 2005). The mean scores varied amongst variables, with mathematical modelling competency having M = 0.898 and SD = 0.318, metacognition having M = 3.884 and SD = 0.486, other-approach goal having M = 5.105 and SD = 1.227 and other-avoidance goal having M = 5.571 and SD = 1.046.

4.2. Measurement models

The measurement model was used to confirm that the unobserved variables were reflected by the observed variables before evaluating the hypothetical structural model. The measurement model of metacognition indicated an acceptable model fit, with $\chi^2 = 325.454$, $\chi^2/df = 1.98$, RMSEA = .043, TLI = .96 and CFI = .97. The CFA model in Figure 2 was the final measurement model that indicated the relationship between the factor and the items.

Figure 2 indicates that the loading of all items was between 0.66 and 0.78 and surpassed the standard score of 0.5 (Awang, 2012). The measurement model of mathematical modelling competency presented a good fit between data models and sample sizes, with $\chi^2 = 232.916$, $\chi^2/df = 1.29$ CFI = 0.98, TLI = 0.97 and RMSEA = 0.023. The CFA model in Figure 3 was the final measurement model that indicated the relationship between the factor and the items.

Figure 3 indicates that the loading of all items was between 0.61 and 0.84 and surpassed the standard score of 0.5 (Awang, 2012). The performance goal measurement model revealed an acceptable model fit at $\chi^2 = 12.236$, $\chi^2/df = 1.530$, CFI = 0.99, TLI = 0.99 and RMSEA = 0.031. The CFA model in Figure 4 was the final measurement model that indicated the relationship between the factor and the items.

Figure 4 indicates that the loading of all items was between 0.82 and 0.91 and surpassed the standard score of 0.5 (Awang, 2012). The results of the factor analyses are provided in Table 2.

4.3. Structural model

The hypothetical structural model in Figure 5 was the final structural model that indicated the relationship amongst metacognition, performance goal and mathematical modelling competency. The results reveal a good fit between data models and sample sizes, with $\chi^2 = 1610.341$, $\chi^2/df = 1.505$, RMSEA = 0.031, TLI = 0.941 and CFI = 0.944 (Table 3).

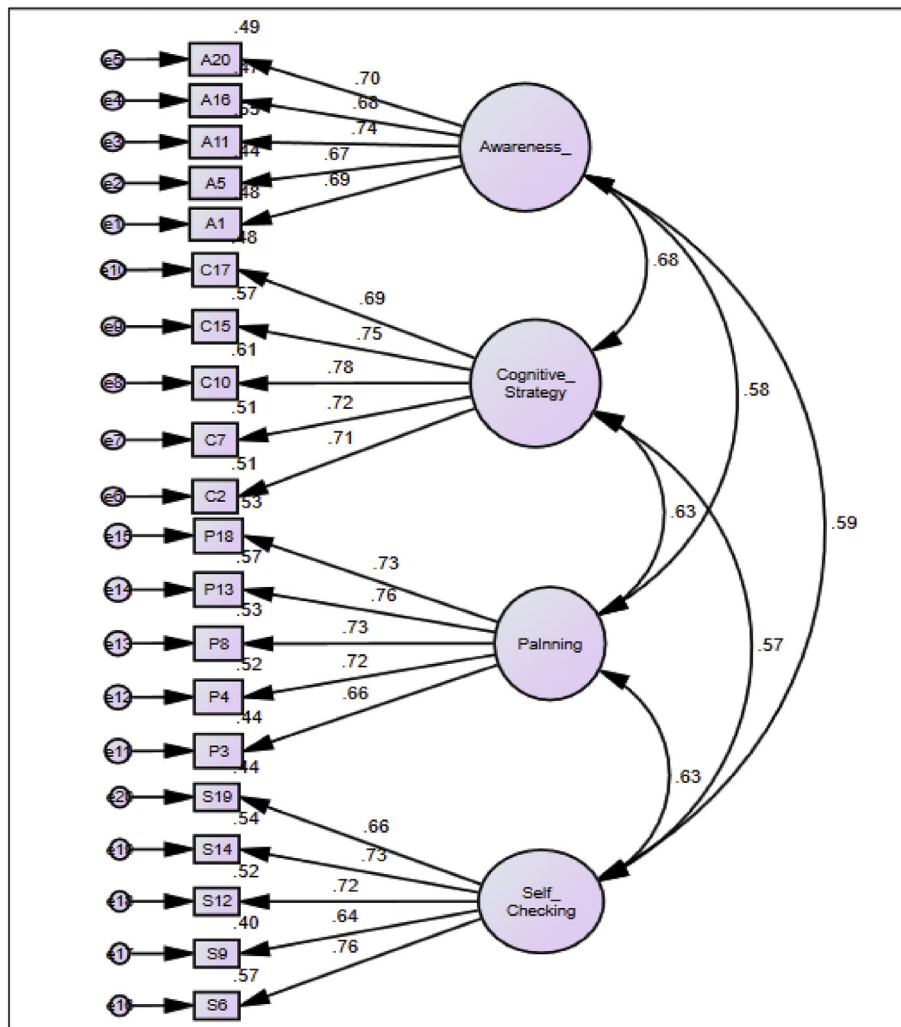**Figure 2.** CFA for metacognition.

4.4. Relationships between metacognition goal and mathematical modelling competency

We assumed that the metacognition goal positively affects mathematical modelling competency. Significant relationships were observed between the two constructs ($\beta = 0.527$, t = 7.126, $p < 0.05$). Students who utilised metacognition performed well in terms of mathematical modelling competency, thus confirming that metacognition is one of the factors that contribute to mathematical modelling competency.

4.5. Relationships between performance goals and mathematical modelling competency

We hypothesised that other-approach and other-avoidance goals negatively affect mathematical modelling competency. However, the students' other-approach ($\beta = 0.011$, t = 0.649, $p = 0.516$) and other-avoidance ($\beta = -0.032$, t = -1.713, $p = 0.087$) goals did not affect their mathematical modelling competency. Thus, H2 is not fully supported; the other-approach and other-avoidance goals of students are unimportant in improving their mathematical modelling competency.

Table 1. Bivariate correlation between constructs.

Variable	1	2	3	4
1. Mathematical modelling competency	1	.537**	.379**	.313**
2. Metacognition		1	.509**	.485**
3. Other-approach goal			1	.607**
4. Other-avoidance goal				1
Skew	.093	-.294	-.655	−1.109
Kurtosis	−.136	1.827	.333	1.447
M	.898	3.884	5.105	5.571
SD	.318	.486	1.227	1.046

** Correlation is significant at the 0.01 level (2-tailed).
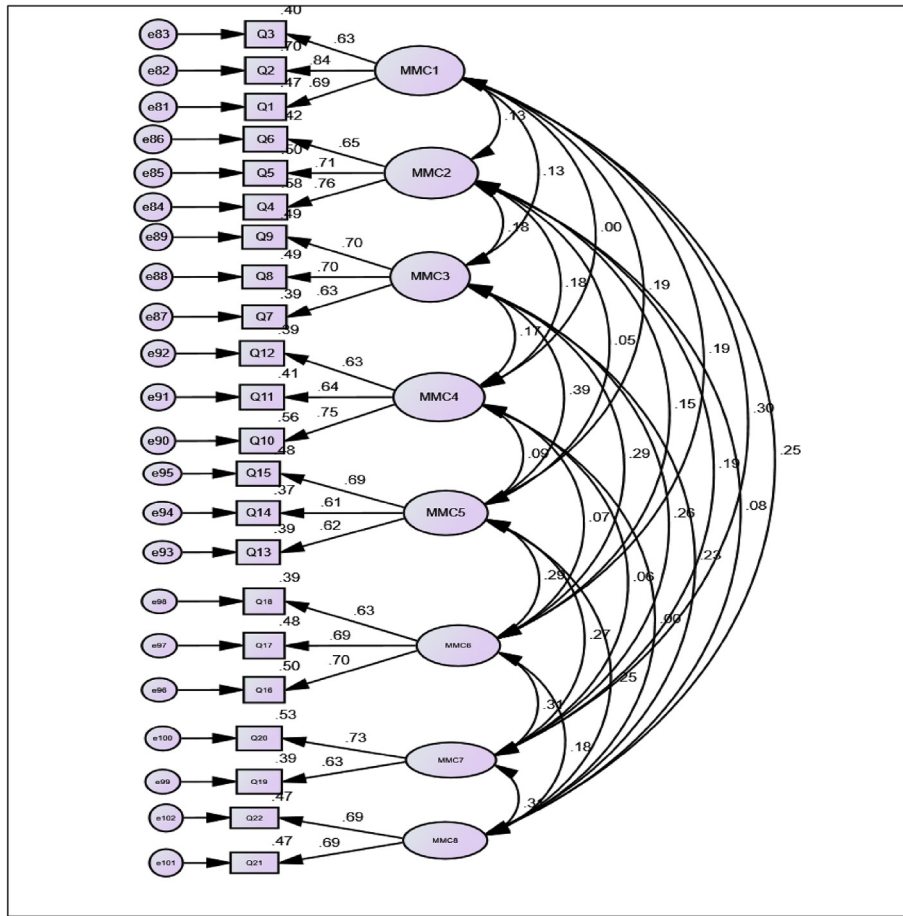
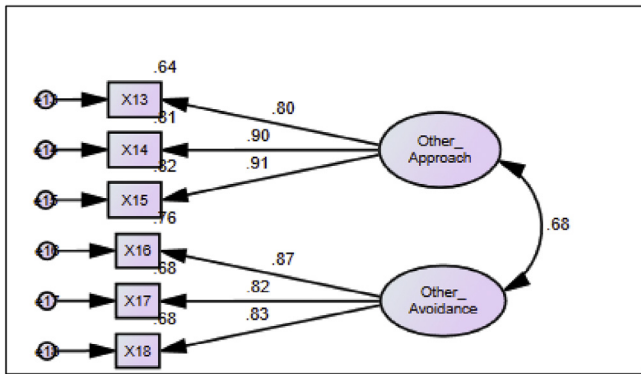**Figure 3.** CFA for mathematical modelling competency.
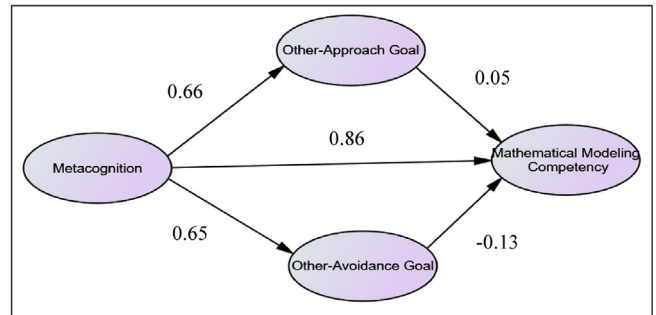

Figure 4. CFA for performance goal.

Figure 5. Final model of the study.

Table 2. Examination of the measurement model.

Model	χ^2	χ^2/df	CFI	TLI	RMSEA
Metacognition	325.454	1.980	0.970	0.960	0.043
Mathematical modelling competency	232.916	1.290	0.980	0.970	0.023
Performance goal	12.236	1.530	0.990	0.990	0.031
Measurement standard	$p > 0.05$	<5.00	>0.900	>0.900	<0.08

Note: χ^2: chi-square goodness of fit; df: degrees of freedom; CFI: comparative fit index; TLI: Tucker–Lewis fit index; RMSEA: root mean-square error.

Table 3. Results of the hypothetical structural model.

Parameter	Measurement standard	Coefficient
$\chi2$	$p > 0.05$	1610.341
χ^2/df	<5.00	1.505
RMSEA	<0.08	0.031
TLI	>0.900	0.941
CFI	>0.900	0.944

Note: χ^2: chi-square goodness of fit; df: degrees of freedom; CFI: comparative fit index; TLI: Tucker–Lewis fit index; RMSEA: root mean-square error.

Table 4. Output of the mediating effect.

Path	Direct effect		Indirect effect		Result
	β	p values	β	p values	
MC→OAP→MMC	0.738	0.003	0.056	0.199	No Mediation
MC→OAV→MMC	0.794	0.004	-0.001	0.943	No Mediation

Note: MC: metacognition; OAP: other-approach goal; OAV: other-avoidance goal; MMC: modelling competency.

4.6. Mediating effects of the two performance goal sub-constructs on the relationships between metacognition and mathematical modelling competency

Table 4 presents the results of the mediating effect analysis of the two performance goal sub-constructs.

The mediation effects were determined via bootstrapping analysis to affirm the indirect effect of the two performance goal sub-constructs. The other-approach ($\beta = 0.056, p > 0.05$) and other-avoidance ($\beta = -0.001, p > 0.05$) goals were not significant mediators of the relationship between metacognition and mathematical modelling competency. Therefore, H3 is not fully confirmed; metacognition has a direct significant effect on mathematical modelling competency.

5. Discussion

Guided by a model promoted by Biccard and Wessels (2011) and empirical evidence, the present work examined a model that includes meta-cognitive behaviour and mathematical modelling competency with the indirect effects of two performance goal sub-constructs, namely, other-approach and other-avoidance goals, via SEM. Whether and how meta-cognitive behaviour and performance goal contribute to the improvement of students' mathematical modelling competency must be studied because prospective mathematics teachers need to engage continually in realistic problem solving, including complicated systems under interdisciplinary contexts. We discovered that metacognition affects mathematical modelling competency. Our results are in line with several previous findings (e.g. Bonnett et al., 2016; Callan et al., 2016; Yusnaeni and Corebima, 2017) possibly because metacognition promotes the use of general approaches. These strategies include task analysis, problem representation, prediction, planning, monitoring, checking, reflection and evaluation of success (Pennequin et al., 2010) because several mathematical modelling competencies require pupils to simplify assumptions, clarify the goal and formulate the problem. The application of metacognitive approaches also enables pupils to be sensitive to and understand a problem, commit a few errors in the learning process, improve their self-regulation skills and enhance their self-confidence (Sahin and Kendir, 2013). The four metacognition sub-dimensions are vital to a mathematical modelling classroom when implementing a modelling cycle.

Our study did not establish a significant and direct correlation between performance goals and mathematical modelling competency. Our findings do not corroborate those of prior studies (i.e. Liu et al., 2017; Mirzaei et al., 2012), indicating that other-approach and other-avoidance

goals are negatively connected to achievement (Matos et al., 2017; Stoeber et al., 2015). We also found that these sub-constructs are not vital in promoting the mathematical modelling competency of students. A possible reason is the perception of ability. Students who utilise performance goals (i.e. maladaptive students) exhibit challenge avoidance and slight persistence in the face of difficulty (Dweck, 1986; Nicholls, 1984). The presence of performance goals in a mathematical modelling classroom produces weakness in the achievement setting, such as selection of easy tasks, withdrawal of effort in the face of failure and decrease in task enjoyment. These activities contradict the process and results of mathematical modelling, in which student answers are not limited to brief responses (Lesh and Lehrer, 2003). However, the task information and required results need to be interpreted (Zawojewski, 2010).

The bootstrapping analysis proved that a component of performance goal does not play a full mediating role in the relationship between metacognition and mathematical modelling competency. Thus, the two sub-constructs may not be meaningful factors distributing metacognition impacts on mathematical modelling competency. Our findings partially support those of prior studies that discovered that (1) other-approach goals have no mediating effects on the relationship between competence beliefs and anxiety (Putwain and Symes, 2012) and (2) performance-avoidance goals are mediators of the negative relationship between self-handicapping and exam performance and GPA (Elliot and Church, 2003). One of the possible reasons is that metacognition is the active control over cognitive processes involved in the learning process (Livingston, 2003). Therefore, the presence of mediating effects of other-approach and other-avoidance goals does not influence students to evaluate their competence on the basis of an interpersonal standard (e.g. 'do better than others' or 'avoid doing worse than others'), although students with performance goals need to seek additional help (Yang et al., 2016). McCollum and Kajs (2007) clarified that students who hold achievement goals in the classroom generally self-regulate via self-checking and organisational approaches; they are also adaptive to failures in particular tasks.

6. Conclusions and limitations

Only metacognition has been reported to have a significant effect on students' mathematical modelling competency. The results of the current study provide further evidence that metacognition positively affects mathematical modelling competency, whereas other-approach and other-avoidance goals do not. The two performance goal sub-constructs are not mediators because their presence in a mathematical modelling classroom enhances the relationship between metacognition and mathematical modelling competency. The current findings do not fully support the a priori model in the Indonesian setting. The implication for teachers is that they should support pupils to enhance their metacognition and decrease performance goals in solving complicated tasks in mathematical modelling competencies by offering suitable learning methods and a sufficient learning environment. This research has several limitations. First, the definition of mathematical modelling competency utilised in this article is slightly limited. Hence, an experimental research involving mathematical modelling competency as a vehicle should be conducted. Second, the relationship amongst metacognition, performance goal and mathematical modelling competency in correlational

design is difficult to explain thoroughly, although SEM suggests outputs about causal relationships.

Declarations

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