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Achievement Goals, Metacognition and Horizontal Mathematization: A Mediational Analysis

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Abstract **– When it comes to providing pupils with real-world experiences, mathematical modelling is essential. The objective of this study is to test the interrelationships between metacognition and goals of achievement, which was predicted to influence horizontal mathematization. Female students accounted for 89.8% of the 538 valid participants, while male students accounted for 10.2%. The study was conducted using a correlational method to examine the level of correlations among metacognition, goals of achievement, and horizontal mathematization. Confirmatory factor analysis (CFA) using AMOS 18 was utilized to compute the gathered data. We found goals of achievement, cognitive strategy, and self-checking were observed to influence horizontal mathematization. However, the SEM analysis found no significant relationships between awareness and planning strategies toward horizontal mathematization. Sub-dimensions of metacognition served as partial mediators of the effect of goals of achievement on horizontal mathematization. We expand the current horizontal mathematization literature by presenting these dynamic connections.**

Keywords **– Achievement goal; AMOS, factor analysis; horizontal mathematization; metacognition.**

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1. Introduction

The benefit of mathematical modelling (or mathematization) in mathematics instruction is well acknowledged. Mathematical modelling is critical in presenting students with real-world experiences. According to recent research, modelling ideas should be employed as ways to boost science, technology, engineering, and mathematics (STEM) competence [1] across all stages of education, from primary to higher [2], as well as the transformation of skills and knowledge between situations within and outside of the STEM disciplines. Recently, based on systematic review [3], [4], research on mathematical modeling has been studied in term of cognitive and affect-related issues. There has been few research on the elements that may impact learners' modelling competency such as reading comprehension [5], achievement goals [6] and students' engagement [7]. However, previous research has shown that teachers found it challenging to use mathematical modelling exercises [8, 9].

Students usually fail to comprehend real-world situations and arrange and simplify the information provided. The goals of achievement concentrate on the growth of competence finding and facing barriers by task mastery which influence academic achievement [10] and metacognition [11], [12]. Students holding achievement goal orientation in the regular classrooms have more effective strategies, more positive attitude, prefer challenging tasks, and believe strongly on their successes following their self-efforts [13]. At the same time, other researchers also believe that both goals of achievement [14] and metacognition are important factors towards mathematics achievement, especially in the process of mathematization or modeling. Based on the work by Sahin and Kendir [15], metacognitive strategies are important to understand problems, plan and control learning, and be conscious of the problem-solving process. Also, according to Vorhölter [16], regulation techniques and assessment strategies should be improved.

Only a few studies, however, have documented how goals of achievement might be associated with horizontal mathematization [17] or how metacognition could have indirect effects between goals of achievement and horizontal mathematization [18]. By focusing on the direct and mediating role of the association between goals of achievement, metacognition, and horizontal mathematization, the current research addresses this gap. The mediating role are the sub-construct of metacognition. Hassan and Rahman [19] indicated that academic accomplishment was mediated by metacognition aspects. By presenting these dynamic connections, we expand the current horizontal mathematization literature.

1.1. Theoretical Framework

Modeling has been employed variously in present literature [20]. According to Biccard and Wessels [21], mathematical modeling competence applies to three distinct aspects of metacognitive skills, affective and cognitive. Metacognitive skills and affective are not regarded as positive benefits but are vital constituents of modeling competency. In the present work, the conception of mathematical modeling competency refers to the cognitive dimension. Modeling competency include skills to simplify assumptions, clarify the objective, formulate the issue, and assign variables, establish parameters and constants, formulate mathematical expressions, choose a model, interpret graphic, link to the real context [22].

According to Galbraith [23], mathematizing begins from understanding the problem to solving problems. In particular, in the current study, we define mathematizing as simplifying assumptions, clarifying the objective, formulating the issue, and assigning variables, establishing parameters, formulating mathematical expressions, and choosing a model. This process can be seen as horizontal mathematization. This is in agreement with Freudenthal [24] who indicated that horizontal mathematization moves to the world of symbols or numbers from the world of reality or fact. Therefore, we measure horizontal mathematization using the mathematical modeling measurement created by Haines and Crouch [22]. We employed six competencies in mathematical modeling, which are simplifying assumptions, clarifying the objective, formulating the issue, and assigning variables, establishing parameters, formulating mathematical expressions, and choosing a model. Based on past study on the effects of achievement goals and the sub-construct of metacognition on horizontal mathematization, we postulated a priori model (Figure 1).

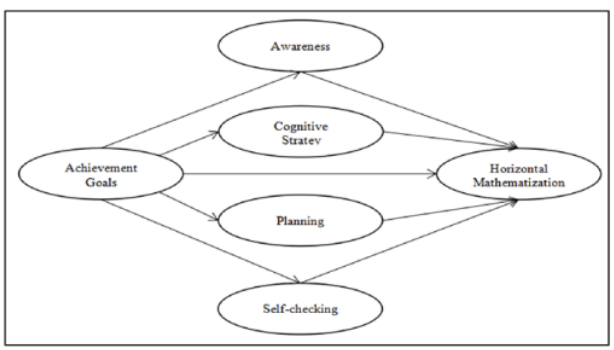

Figure 1. A priori model

1.2. Achievement Goals

Achievement goals refer to competence-based end in which individuals try to either approach or avoid [25]. There are various types of model of achievement goals [26]. The new model is a 3 x 2 model of achievement goals that intertwine dynamic structures [27]. Based on the 3 x 2 framework, mastery is a goal that focuses on achieving competence as determined by task-based or intrapersonal criteria meanwhile a performance objective is one that focuses on achieving competence as determined by an external observer. The task-approach goal is defined as the achievement of the absolute task and (approaching success) (e.g., "do the task correctly") and the task-avoidance goal is the achievement of an absolute task (e.g., "avoid doing the task incorrectly"). Additionally, the self-approach goal refers to the achievement of intrapersonal terms, self- avoidance goal refers to the achievement of intrapersonal terms, the other-approach goal is the achievement of interpersonal terms, and other-avoidance goals refer to the achievement of interpersonal terms.

1.3. Metacognition

Schraw and Moshman [28] define conceptions of metacognition as declarative knowledge, procedural knowledge, and conditional knowledge. O'Neil and Abedi [29] view the metacognitive inventory of learners operationally as a dimension containing the following subscales or sub-domainss: cognitive strategy, planning, awareness and monitoring. Previous researchers emphasize the importance of metacognition toward the success of mathematical modeling, especially in horizontal mathematization [30], [17]. Empirical evidence has supported that metacognition is richly associated with mathematical achievement [31], Yusnaeni and Corebima [32] revealed that the direct link from metacognition to problem-solving skills. Accordingly Brown [33] also indicated that meta-cognitive activity leads pupils to choose strategies to help understand the task, plan courses of action, observe execution action while employing strategies, assess the outcomes of strategies, and improve or abandon non-productive strategies. Interestingly, the presence of metacognitive competencies is helpful for obstacles and opportunities in the horizontal mathematization process [30].

1.4. Related Research

The direct and positive correlation between goals of achievement and horizontal mathematization has been documented from a number of studies in other domains. Research reveals that goals of achievement are highly associated with the problem-solving success of students [34]. In the 3 x 2 achievement goal framework, students who indicated more solution-oriented (task-based goals) predict better solution (problem detection, solution evaluation, solution confirmation, and strategy) in collaborative learning [35], self-concept [36], self-competence [37], behavioral engagement [38] and material absorption [27]. However, a number of research on goals of performance, which refer to other-based goals, are not consistent. For example, performance goals can predict direct and significant learning outputs [39].

Mangels et al [40] found that students who under a performance frame would regulate parieto-occipital activity associated with perceptual processing. Furthermore, it has been shown that performance goals predict perceived academic competence [41]. Readiness, planning, and action control also are associated with higher performance goals [42]. This behavior is important in the modeling classroom since horizontal mathematization requires good planning and problem-solving. In brief, the constructive activity would be useful to mediate the relationship between goals of achievement and learning. Hence, because of the positive correlation between goals of achievement and positive outcome and sub-construct of problem-solving [10], [39], we expected that task-, self- and other-approaches goals positively affect horizontal mathematization, whereas task-, self, and other-avoidance goals negatively affect horizontal mathematization.

Meta-cognitive behavior has been proposed as one of the most prominent factors toward goals of achievement [12]. In terms of mastery approach goals, pupils who hold mastery goal orientation in the classroom are usually self-regulated by employing organizational techniques and self-monitoring; they are also resilient in the face of failures on particular tasks [43]. Further evidence comes from a positive and direct relationship between students' achievement goals (mastery-approach, performance-approach, and performance-avoidance) and metacognition in first-grade female students, but not mastery avoidance [44]. Third-year medical students' learning goals group are more effective due to elevated metacognition and task engagement among pupils [11]. Lin and Wang [45] found that mastery approach goals are positively associated with self-regulated learning, meanwhile, performance-avoidance goals are negatively associated with the self-regulatory problem and effort regulation approaches.

Students who employ mastery approach goals within a mathematics classroom encourage meta-cognitive behavior, enhance intrinsic motivation, and help pupils achieve a principal knowledge of mathematical concepts; therewith promoting positive mathematics results [46]. Surprisingly, only mastery approach goals have a positive impact on metacognitive awareness, planning, and monitoring, among three dimensions of achievement goals [47]. In terms of meta-cognition as a mediating effect, Follmer and Sperling [18] found that metacognitive behavior mediated the correlation between executive functioning and self-regulation, and between specific executive functions and self-regulation. Because of the positive correlation between goals of achievement and metacognition [12], we expected that pupils' achievement goals would positively influence the level of metacognition.

1.5. Purpose of the Study

The purpose of this study is to test the interrelationships between metacognition and goals of achievement, which was predicted to influence horizontal mathematization. The research hypotheses were:

1. Achievement goals have a positive influence on students' horizontal mathematization.
2. Sub-construct of metacognition has a positive influence on students' horizontal mathematization
3. Sub-construct of metacognition significantly mediates the achievement goals with horizontal mathematization.

2. Research Methodology

2.1. Design of Research

In the current study, a non-experimental quantitative research approach was used. We follow a correlational research method [48] to test the level of relationship among goals of achievement, sub-construct of metacognition, and horizontal mathematization. Correlational research, which is part of quantitative approach, refers to a non-experimental study in which two variables are measured.

2.2. Participants

Female students accounted for 89.8% of the 538 valid participants, while male students accounted for 10.2%. Of the participants, 133 (24.7%) were the first-year participants, 223 (41.4%) were the second year participants, and 182 (33.8%) were the third year participants. Participants were assumed to have modeling experiences in mathematics education programs and registered for the advanced mathematics course. Since the present study selected groups rather than individuals [48] we employed cluster random sampling.

2.3. Data Collection Tools

The horizontal mathematization test was adapted [22] and involves six sub-constructs. The horizontal mathematization test consisted of 18 multiple-choice questions. Students' correct answers on mathematics modeling tests were coded 2, wrong solution 0, and 1 point for partial credit. The reliability value of the horizontal mathematization test in the present study was excellent (0.82) [49].

Moreover, all-composite reliability (CR) scores of horizontal mathematization dimensions were 0.69 - 0.78 and reached the 0.6 desired criteria. This result showed that internal consistency was quite high. The average variance extracted (AVE) of the six latent variables is 0.50 - 0.63 and surpassed the 0.5 common cut-off scores, which revealed that the present work demonstrates accepted discriminant validity. Hence, each horizontal mathematization item in the present work was employed. O'Neil and Abedi's [29] meta-cognitive inventory was used including four sub-construct to assess metacognition. The metacognition measurement included 20 questions with five-point scoring. The reliabilities were more than 0.70.

Moreover, all CR scores of the sub-dimension of metacognition surpassed the 0.6 common cut-off scores (0.83 - 0.85), which revealed great internal consistency. In terms of discriminant validity, the AVE of the four metacognition sub-dimension was 0.50 - 0.54, which surpassed the desirable criteria value of 0.5. Achievement goals were measured by the 3 × 2 achievement goal measurement [27]. The 3 × 2 achievement goal questionnaire included 18 items with seven-point scoring was employed. The reliabilities were more than 0.70. For internal consistency, CR scores for the goals of achievement are from 0.88 to 0.97 (> 0.6). Likewise, AVE values are 0.71 - 0.92, with high discriminant validity.

2.4. Data Collection Process

A consent letter was supplied to the Department of Investment in Indonesia before the online surveys were completed. The agency then delivered this letter of consent, including its own acceptance letter, to the testing places. In the first section, we obtained biographical information from participants, such as field, gender and academic year level. We intended to look at the factors which were related to the study question in the second half.

2.5. Data Analysis

We utilised IBM SPSS Amos version 18 to evaluate the hypothesised mediation using structural equation modelling (SEM). Also, a model of measurement between the related constructs for each component which was promoted from empirical study and theories was tested. At the same time, the bootstrapping approach using the bias-corrected percentile technique [50] was used to investigate the mediating impact.

However, in this study, the bootstrapping technique has been used with a bootstrap sample of 1000 and a bias correction confidence interval of 95% [51]. The score of chi-square ($\chi2$) (P>0.05), normed chi-square ($\chi2$/df), adjusted goodness-of-fit index (AGFI>0.90), Tucker-Lewis index (TLI>0.90), root-mean-square error of approximation

(RMSEA<0.08) and comparative fit index (CFI>0.90) [51] used to test model adequacy. Moreover, Average Variance Extracted (AVE), composite reliability (CR), and Cronbach's alpha coefficients were computed. The Alpha coefficient of 0.60 to 0.70 was considered good [52]. According to Mohamad et al [51] the CR should be greater than 0.60 and the AVE was greater than 0.50.

3. Result and Discussion

3.1. Result

CFA technique employing AMOS 18.0 was used in the present study. According to Kline [53] before running computation with AMOS, multivariate normality and univariate normality have to be met. To test normality, the kurtosis and skewness scores of each construct was −1.96 to +1.96 [52] employed. According to Mardia [54] the critical ratio (C.R) and multivariate kurtosis values should be investigated. When the C.R for all the constructs in the suggested model is less than 8.0, the data appears to be not normal [53]. In the Indonesian context, all the components in the measures of horizontal mathematization, goal of achievement, and metacognition exhibit univariate normality after an initial computation.

The kurtosis score was 228.145 with a C.R of 32.828 for Indonesian context; this showed that the data set in the present research is not normal. Hence, a bootstrapping approach was employed to get more precise estimations given the current batch of data [55]. The correlation between horizontal mathematization and achievement goals was significant ($r = .219$, $p < 0.01$), horizontal mathematization and metacognition was significant ($r = .588$, $p < 0.01$) and goals of achievement and metacognition was significant ($r = .450$, $p < 0.01$) (see Table 1). Since the correlation matrix showed correlations of not more than 0.90, this correlation suggested that the variables' discriminant validity was achieved [53].

Table 1. Inter-connections among constructs

	Horizontal Mathematization	Achievement Goals	Metacognition
Horizontal mathematization	1	.219**	.588**
Achievement goals		1	.450**
Metacognition			1

The CFA outputs of achievement goals revealed a perfect match to the data, $\chi^2 = 208.265$, $\chi^2/df = 1.736$ CFI = 0.989, TLI = 0.987 and RMSEA = 0.037. The CFA outputs of metacognition also revealed a good fit to the data, $\chi^2 = 454.565$, $\chi^2/df = 2.772$ CFI = 0.927, TLI = 0.915 and RMSEA = 0.057. The CFA outputs of horizontal mathematization also revealed a perfect match to the data, $\chi^2 = 152.541$, $\chi^2/df = 1.271$ CFI = 0.984, TLI = 0.980 and RMSEA = 0.022.

SEM Outputs in Figure 1 in the present work showed an excellent fit to the data, $\chi^2 = 2312.360$, $\chi^2/df = 1.581$ CFI = 0.944, TLI = 0.941 and RMSEA = 0.033. The factor loadings for each of the four sub-dimensions of metacognition ranged from 0.60 to 0.76, those for the sub-dimensions of goals of achievement ranged from 0.82 to 0.97, and those for the six sub-dimensions of horizontal mathematization ranged from 0.62 to 0.83. The loading factor scores were higher than the desired standard of 0.50 [52]. Also, the CFA model provided in Figure 2 became the completed model that demonstrated connections between metacognition, goals of achievement, and horizontal mathematization. The final result generated from the present work can be seen as an alternative in describing the prior analysis on the interrelationships between metacognition, goals of achievement, and horizontal mathematization.

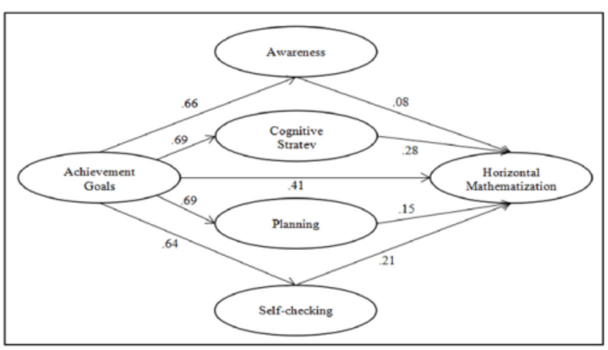

Figure 2. Structural model

We hypothesized that sub-dimensions of metacognition goal positively influence horizontal mathematization. The cognitive (β = 0.153, t = 2.888, $p < 0.05$) and self-checking (β = 0.087, t = 2.434, $p < 0.05$) influenced the horizontal mathematization of students. However, planning (β = 0.071, t = 1.686, $p = 0.092$) and awareness (β = 0.038, t = 0.949, $p = 0.343$) did not influence their horizontal mathematization. Thus, H1 was partially supported. Thus, learners who used cognitive strategy and self-checking performed well in horizontal mathematization. In contrast, awareness and planning were not important factor in horizontal mathematization.

We hypothesized that sub-dimensions of metacognition goal positively influence achievement goals. The cognitive (β = 0.483, t = 9.875, $p < 0.05$) and self-checking (β = 0.581, t = 10.143, $p < 0.05$), planning (β = 0.570, t = 10.347, $p < 0.05$) and awareness (β = 0.534, t = 10.382, $p < 0.05$) influenced achievement goals. Thus, H2 was completely supported. Thus, students who used achievement goals done well in sub-dimensions of metacognition.

We hypothesized that achievement goals positively influence horizontal mathematization. Achievement goals were a positive predictor of horizontal mathematization (β = 0.155, t = 2.406, $p = 0.016$). Thus, H3 was fully supported. Learners' achievement goals were vital in improving horizontal mathematization.

We anticipated that sub-dimensions of metacognition had mediating impacts on the connection between goals of achievement and horizontal mathematization. Metacognition dimensions may be valuable domains which relate learners' goals of achievement to horizontal mathematization. Table 2 shows the mediating role analysis results of the four metacognition components.

Table 2. Output of the mediating role

Path	Direct Effect		Indirect Effect		Result
	β	p Values	β	p Values	
AG→AW→HM	0.581	0.001	0.209	0.002	Partial Mediator
AG→CS→HM	0.494	0.002	0.293	0.002	Partial Mediator
AG→PL→HM	0.523	0.002	0.250	0.002	Partial Mediator
AG→SC→HM	0.551	0.002	0.224	0.002	Partial Mediator

Note: *AG: goals of achievement; AW: awareness; CS: strategy of cognitive; PL: planning; SC: self-checking; HM: horizontal mathematization*

Table 2 reveals the result of indirect effect of sub-construct metacognition between achievement goals and horizontal mathematization. Partial mediating role of awareness ($β = 0.209$, $p < 0.05$) for achievement goals on horizontal mathematization was positive ($β = 0.581$, $p < 0.05$). Partial mediation role of cognitive strategy (β = 0.239, $p < 0.05$) for goals of achievement on horizontal mathematization (β = 0.494, $p > 0.05$) was discovered. In addition, partial mediation effect of planning (β = 0.250, $p < 0.05$) for goals of achievement on horizontal mathematization (β = 0.523, $p > 0.05$) was discovered while a partial mediating role of self-checking (β = 0.224, $p < 0.05$) for goals of achievement on horizontal mathematization (β = 0.551, $p > 0.01$) was discovered. The results corroborate that learners who hold goals of achievement with high sub-construct metacognition would probably have better horizontal mathematization.

3.2. Discussion

The effects of achievement goals on horizontal mathematization-associated measures were fully confirmed in our current research. The impacts of achievement goals on pupils' horizontal mathematization corroborate previous investigation results in mathematics achievement [10] and problem-solving success of students [34]. One of the possible rationales is that pupils who hold a high level of achievement goals promote better problem detection, solution evaluation, solution conformation, strategy, self-competence, behavioral engagement, and material absorption. This is in line with statements with previous studies [35], [38]. Interestingly, pupils who have both mastery goals (task-based goals and self-based goals) and performance goals (other-based goals) regulate the neural activity, and frontal-temporal activity linked with semantic processing, and regulate parieto-occipital activity associated with perceptual processing, which influences successful learning [40]. Since the process of horizontal mathematization requires collaborative learning, students–teacher relationship, peer inclusion, and conflict [56] and behavioral engagement [38] could be enhanced by achievement goals.

The same effects were also found for the effect of sub-dimension of metacognition on horizontal mathematization, which partially confirmed in our current research. SEM outputs revealed significant effects of cognitive strategy and self-checking on horizontal mathematization, whereas awareness and planning are not important factors in the process of horizontal mathematization. Our findings confirm previous studies in which cognitive strategy and self-checking predicted modeling abilities than those less experienced in cognitive strategy and self-checking [57]. One of the potential explanations is that learners who rely on cognitive strategy and self-checking are more open to correctly interpreting a problem and, of course, making less mistakes in the classroom activities, enhancing self-regulation abilities and self-confidence. Moreover, self-reflective activities help pupils remain focused on learning deeply and allowed them to keep engaged and motivated through study [58].

Likewise, cognitive strategy factor contains procedural knowledge escalating the opportunity of attaining the goals of the task [59] and reducing obstacles [30]. Compared to cognitive strategy and self-checking, this study found that awareness and planning are not predictors toward horizontal mathematization. This was stated by Abdullah et al [60] who indicated that pupils lack planning, implementation, and revision skills learning processes. This is also in line with the expression of [61] who indicated that several processes in the process of metacognitive awareness take places such as planning about efforts that are needed and time which should be spent.

The computation of bootstrapping revealed that metacognition dimensions play a partial mediating impact in the interrelationship between goals of achievement and horizontal mathematization. Metacognition dimensions may be valuable factors that associate learners' goals of achievement and horizontal mathematization. These results are consistent with prior work Hassan and Rahman [19] that discovery metacognition dimensions as mediators in academic achievement. This output can be explained by prior works, which indicated a positive relationship between achievement goals and metacognition [12].

Moreover, McCollum and Kajs [43] stated that pupils who have goals of achievement in the mathematics classroom are usually self-regulated by employing self-checking and organizational technique; they can also adapt to losses in certain tasks. This finding implies that the presence of metacognition sub-dimension in the horizontal mathematization would maximize their achievement goals, which affects horizontal mathematization.

Another possible rationale is that metacognition is categorized as higher-order thinking, including direct influence over the mental processes that take place throughout the teaching and learning process.

4. Conclusion

The value of mathematical modelling (or mathematization) in mathematics training has been widely recognised in recent years. The current study confirmed the importance and significance of considering sub-dimensions of metacognition and achievement goals toward horizontal mathematization. At the same time, sub-dimensions of metacognition served as a partial mediator of the impact of achievement goals on horizontal mathematization. By clearly summarizing these findings, we argue that the four sub-dimensions of metacognition are significant factors that can be affected by goals of achievement, and in turn, affect horizontal mathematization.

5. Implications, Limitations, and Future Research

The findings imply that sub-dimensions of metacognition appear to be important factors in the interrelationship between goals of achievement and horizontal mathematization; hence the outcome of the horizontal mathematization of students in Indonesia can be enhanced by encouraging these factors. Lecturers or teachers should improve strategies for regulating and strategies for evaluating. Also, according to Vorhölter [16] regulation techniques and assessment strategies should be improved. Moreover, upcoming studies should pay attention toward instrument employed since the instrument of horizontal mathematization is part of modeling competency. Developing new instrument of horizontal mathematization is valuable to measure the construct.

Our findings recommend examination of the impacts of sub-dimension of metacognition and sub-dimension of achievement goals together toward sub-dimension horizontal mathematization. For future research, since this study uses correlational study, to view the causal impact of these factors toward horizontal mathematization, an experimental study should be applied. According to the framework proposed by Ferri and Lesh [62] effective modeling competency involves feelings, dispositions, attitudes, beliefs, and a variety of metacognitive functions. Future studies should widen the study of attitudes and beliefs toward horizontal mathematization.

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