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The Effect of Mathematical Habits of Mind and Early Mathematical Ability on Modeling Ability of High School Students

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ABSTRACT

Modeling mathematics serves as a bridge between the processes of translating real-world problems into mathematics. In reality, however, students' mathematical modeling skills, including their knowledge of derivative applications, remain subpar. This study is intended to determine the relationship between mathematical modeling skills, mathematical habits of mind (MHoM), and early mathematical ability (EMA). This research employed a quantitative methodology with mix method sequential explanatory design. The method used a quantitative and qualitative approach. The first quantitative phase is used, then explained more deeply through the qualitative phase. Sample in this study were 36 eleventh-grade students from one of Tasikmalaya's senior high schools. In this investigation, the EMA was the previous semester's math report card grade. A mathematical modeling ability test question and an MHoM questionnaire were administered to students, and the quantitative analysis of the results followed. This study demonstrates that the relationship between MHoM and EMA has a 31.2% modeling capability. In addition, a one-point increase in MHoM and EMA increases the average mathematical modeling ability of pupils by 1,570 and 2,241. Therefore, it can be concluded that MHoM and EMA have a positive effect on mathematical modeling ability.

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A. INTRODUCTION

The advancement of technology in the twenty-first century necessitates that every individual considers critically and creatively when confronted with problems. In addition, each individual must comprehend the concept of knowledge and its practical application (Beers, 2011). Mathematics is one of the challenging subjects. When solving problems by applying mathematics, there are important aspects, namely the five standard mathematical processes NCTM (2000), including problem-solving, reasoning and proof, communication, connections, and representation. But besides that, the most important aspect is the ability to do mathematical modeling.

Mathematical modeling skills involve mathematics itself, specifically the use and application of mathematics in various contexts, or the process of analyzing, reasoning, and effectively communicating mathematical ideas when proposing, formulating, solving, and interpreting mathematical problems in various contexts (OECD, 2004). Mathematical modeling is the process of translating real-world problems into mathematics, solving them mathematically, and returning to the original context (Blum & Borromeo, 2009). This process bridges the mathematization process. Therefore, the capacity to model mathematics is one of the most important factors when solving mathematics-related contextual problems.

When students solve contextual problems, there is a mathematical modeling process because they must first simplify the problem by constructing a mathematical model, then solve it until a solution is found, and lastly return it to its original context. The process of mathematical modeling is related to other mathematical abilities, such as communicating, developing, and implementing problem-solving strategies, or working mathematically, such as reasoning, calculating, etc (Mogens, 2003). According to research by Özdemir & Üzel (2018), mathematical modeling plays a significant role in mathematics by serving as a useful context for the development of problem-solving skills, emphasizing mathematical connections, discussing various aspects of learning, and improving students' mathematical comprehension.

High school students continue to make errors in mathematical modeling or fail to use it at all when solving contextual problems (Bahir & Mampouw, 2020). According to Fitri et al. (2019), when solving contextual problems on one of the mathematics topics, namely derivative applications, students made 44% fewer errors in question comprehension, 49% fewer errors in transformation, and 28% fewer errors in process skill. Based on Blum & Leiß (2007), these errors are associated with the stages of the mathematical modeling process, including constructing, mathematizing, and working mathematically.

The steps of the modeling process from Blum & Leiß (2007), as depicted in Figure 1, are organized into six levels of competence in mathematical modeling abilities by Ludwig & Xu (2010), namely: (1) Level 0 (step 1 is constructing); (2) Level 1 (step 1 to before step 2, namely simplifying/structuring); (3) Level 2 (step 2 is simplifying/structuring); (4) Level 3 (step 3 is mathematizing); (5) Level 4 (step 4 is working mathematically); (6) Level 5 (steps 5, 6, and 7 are interpreting, validating, and exposing), as shown in Figure 1.

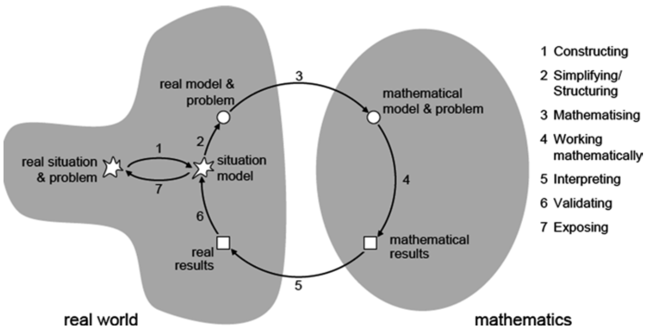

Figure 1. Blum & Leiß (2007) Modeling Cycle

Incorporating modeling competencies into the long-term learning process is one way to enhance this (Blum & Borromeo, 2009). In addition, the teacher aims to develop learning strategies and instructional materials that place an emphasis on mathematical modeling skills. When studying math content in class, assigning homework outside of class, or training students to have mathematical thinking habits or mathematical habits of mind, teachers also encourage students to practice solving contextual problems. Contextual learning improved students' mathematical problem-solving abilities and self-esteem, according to research by (Surya et al., 2017). If students comprehend the steps of the problem-solving process through context-based learning, they will solve complex, difficult, and unstructured problems correctly in the future, according to Yu et al. (2014) concluded that if students understand the steps of the problem-solving process through context-based learning, they will solve problems correctly when facing complex, difficult, and unstructured problems in the future. According to Herawaty & Widada (2018), contextual learning also affects students' conceptual understanding abilities.

Apart from having the ability to understand concepts and the steps to solve mathematics, students should have the habit of thinking. Cuoco et al. (1996) define mathematical habits of mind as a method of thinking that mathematicians use to solve mathematical problems. Students are expected to adopt this mindset in order to comprehend and address any problems they encounter. This mindset is not only capable of solving any problem but also investigates mathematical concepts and is required to comprehend and construct examples, devise problem-solving strategies, and evaluate the solutions found. Based on ÜNVEREN BİLGİÇ (2018) and Yandari et al. (2019), students' mathematical habits of mind contribute positively to the problem-solving process. In addition, a survey (Dwirahayu et al., 2017) concluded that instructors must improve students' thinking habits without their knowledge. They only persist and presume that students' thinking habits have developed well during the learning process, whereas flexible thinking and the application of prior knowledge to new situations have not developed well.

The mathematical habits of mind indicators in this study include nine of the sixteen indicators of Costa & Kallick (2004), including (1) flexible thinking; (2) metacognition; (3) striving to be thorough and precise; (4) asking and raising problems; (5) applying prior knowledge in new situations; (6) thinking and communicating clearly and precisely; (7) taking a responsible risk; (8) persisting or never give up; and (9) controlling impulsivity. This is based on the consideration that these indicators will represent students' mathematical modeling abilities when solving the problems given in this study.

In addition to familiarizing students with mathematical habits of mind, teachers can also assess how far students' early mathematical knowledge and skills have progressed. It attempts to create meaningful learning by connecting students' prior knowledge to the new information they will acquire during their studies. In particular, learning mathematics involves not only repetition but also the development of a conceptual understanding. Koskinen & Pitkäniemi (2022) assert that the following are necessary for mathematics education to produce the greatest results: teacher guidance, continuously assessing students' progress, providing positive feedback, selecting contexts that pique students' interest in mathematics, monitoring student communication quality and guiding it in essential directions, a conducive and efficient learning environment, and an environment in which students are regarded as individuals and instruction is based on their personal values all contribute to improved mathematics learning.

Early mathematical ability is the ability or knowledge a student possesses prior to acquiring new information from the instructor. The students were divided into three categories based on their early mathematical ability: low, medium, and high. The final semester mathematics grades in this study reveal the grouping of students according to their early mathematical ability. Early mathematical ability have a significant impact on mathematics learning outcomes. Early mathematics knowledge and abilities are the most significant predictors not only of later math achievement but also of achievement in other content areas, according to research by Claessens & Engel (2013). Even more strongly predicting adolescent mathematics achievement is mathematical ability between the ages of 54 months and first grade (Watts et al., 2014).

The early mathematical ability of students serves as the foundation for working on a mathematical problem, one of which involves mathematical modeling. This can be taken into account when evaluating the outcomes of students' work on mathematical modeling problems. Students' mathematical habits of mind are considered in addition to their early mathematical abilities, as described in the previous paragraph. This study seeks to determine the effect of mathematical habits of mind and early mathematical abilities on high school students' mathematical modeling skills.

B. METHODS

This is quantitative research using the survey method. The survey method is a research method that collects information from a sample of individuals through their responses to queries developed by researchers (Check & Schutt, 2011). The statistical test are correlational analysis and multiple regression. Correlational analysis is performed to determine the relationship between two or more variables by calculating the correlation between those variables, whereas regression analysis is performed to determine whether an increase or decrease in the independent variable can be achieved by increasing the dependent variable (Sugiyono, 2016). In this study, there are three variables: mathematical modeling ability as the dependent variable, mathematical habits of mind as the independent variable, and early mathematical ability as the independent variable.

This study's participants were all eleventh-grade students from one of the public secondary schools in Tasikmalaya. This study's sample consisted of one class with 36 pupils. The sample was selected using the technique of purposive sampling in consideration of the fact that the academic abilities of the pupils in a single class were diverse. Then, one individual was chosen from each group of 36 based on their mathematical habits of mind and early mathematical abilities. It aims to specifically explore the relationship between mathematical modeling abilities, mathematical habits of mind, and early mathematical abilities.

All students participate in this study by receiving test and non-test materials, then participating in interviews with student representatives. This is necessary to obtain clearer and more detailed information regarding the results of the tests that students take. The testing instrument is a series of queries designed to evaluate mathematical modeling skills. In the meantime, non-testing instruments consisted of questionnaires on mathematical habits of mind. The test questions consist of three descriptive questions related to derivative applications. In the meantime, the questionnaire comprises fourteen statements that were formulated based on an indicator of mathematical habits of mind, there are flexible thinking, metacognition, striving to be thorough and precise, asking and raising problems, applying prior knowledge in new situations, thinking and communicating clearly and precisely, taking a responsible risk, persisting or never give up, and controlling impulsivity. On a Likert scale, these statements contain positive and negative statements: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). The test and non-test instruments used in this study have gone through a process of validity and reliability.

Mathematical modeling ability data is obtained from test results that have been given scores, grades, and levels that have been achieved. The data will be grouped based on three groups of mathematical habits of mind and three groups of early mathematical abilities. Using MSI (Method of Successive Interval), ordinal data are transformed into interval data based on the results of a scored questionnaire pertaining to mathematical habits of mind. Based on this, the average ($\bar{x}$) and standard deviation (s) obtained are $\bar{x} = 38.673$ and $s = 4.702$. Furthermore, these values are used for grouping the mathematical habits of mind scores of students, which are presented in Table 1.

Table 1. Student MHoM Score Grouping Criteria

Group	Criteria
High	HoM Score $\geq$ 43,376
Medium	33,97 $\leq$ HoM Score $<$ 43,376
Low	HoM Score $<$ 33,97

Meanwhile, data on students' early mathematical abilities were obtained based on the average value ($\bar{x}$) and standard deviation (s) of the student's math report cards and then grouped according to Table 2.

Table 2. EMA Category Placement Criteria

Group	Criteria
High	EMA $\geqslant \bar{x} + s$
Medium	$\bar{x} - s \leqslant$ EMA $< \bar{x} + s$
Low	EMA $< \bar{x} - s$

Mathematical modeling abilities in this study are grouped based on competence according to (Ludwig & Xu, 2010). The level of mathematical modeling ability, as shown in Table 3.

Table 3. Mathematical Modeling Ability Level

Level	Criteria
0	step 1 is constructing
1	step 1 to before step 2, namely simplifying/structuring
2	step 2 is simplifying/structuring
3	step 3 is mathematizing
4	step 4 is working mathematically
5	steps 5, 6, and 7 are interpreting, validating, and exposing

C. RESULT AND DISCUSSION

The results of the mathematical modeling ability tests were examined and analyzed quantitatively and qualitatively through interviews based on the criteria for the level of mathematical modeling ability in Table 3 and in terms of the mathematical habits of mind and early mathematical ability groups. The level of mathematical modeling ability is first grouped based on the mathematical habits of mind group in Table 1. The groupings are presented, as shown in Table 4.

Table 4. Student's Mathematical Modeling Ability Level based on MHoM

MHoM Group	Mathematical Modeling Ability Level
Low	0
Medium	1
High	2

Based on Table 4, it is known that the level of mathematical modeling ability of students in the low mathematical habits of mind group is lower than the level of mathematical modeling ability of students in the medium and high mathematical habits of mind group. Likewise, students in the mathematical habits of mind group had a lower level of mathematical modeling ability than students in the high group. The description indicates that the higher the mathematical habits of mind group, the higher the level of students' mathematical modeling abilities. Furthermore, the level of mathematical modeling ability is grouped based on the EMA group in Table 2. The groupings are presented, as shown in Table 5.

Table 5. Student's Mathematical Modeling Ability Level based on EMA

EMA Group	Mathematical Modeling Ability Level
Low	0
Medium	1
High	4

Based on Table 5, it is known that the level of students' mathematical modeling ability based on EMA has different levels for each group. The level of mathematical modeling ability of students in the high EMA group is higher than that the medium and low EMA groups. Likewise, the medium EMA group had a higher level of student mathematical modeling ability than the low group. The description indicates that the higher the EMA group, the higher the level of students' mathematical modeling abilities. If the level of mathematical modelling ability is viewed from the MHoM and EMA groups, it is presented in Table 6.

Table 6. Student's Mathematical Modeling Ability Level based on MHoM and EMA

EMA Group	Lots of Students	MHoM Group	Mathematical Modeling Ability Level
Low	3	Low	0
	7	Medium	0
	1	High	0
Medium	2	Low	1 and 4
	12	Medium	1
	3	High	1
High	1	Low	1
	6	Medium	2
	1	High	4

Based on Table 6, it can be said that the higher the mathematical habits of mind group and the early mathematical ability, the higher the level of mathematical modeling ability. This will then be tested for correlation and multiple regression to ensure its correctness. The prerequisite analysis test was carried out before carrying out the correlation and multiple regression tests. The prerequisite tests are the normality test, the linearity test, and the multicollinearity test. The prerequisite test results show that the data to be processed is normally distributed, because value of Sig. $= 0{,}07 > \alpha = 0{,}05$. While the results of the linearity test are presented in the following Table 7.

Table 7. Summary of Regression Linearity Test Results

Statistic	MHoM on Mathematical Modeling Ability	EMA on Mathematical Modeling Ability
Lots of Respondents	36	36
Sig. value	0,933	0,179
Conclusion	Linear	Linear

Based on Table 7, it is known that the two variables from each of the independent variables and the dependent variable have a linear regression. So that the prerequisite test of linearity is fulfilled. Furthermore, the results of the multicollinearity test. The multicollinearity test aims to test whether there is a correlation between independent variables. It is known that the value of Sig. for the correlation test of students' MHoM and EMA is 0.686. If value of Sig. = 0.686 > α = 0.05, then H_0 is accepted at the significance level α = 0.05. This means that there is no significant relationship between MHoM and EMA. So there is no multicollinearity between the independent variables. So that the multicollinearity prerequisite test is met. Once the prerequisite test has been met, the correlation test between the independent and dependent variables is carried out, as well as a multiple correlation test.

The results of the correlation test between mathematical modeling abilities and MHoM, it is known that the value of Sig. for the correlation test of students' mathematical modeling ability and MHoM is 0.037. If value of Sig. = 0.037 < α = 0.05, then H_0 is rejected at the significance level α = 0.05. This means that there is a significant relationship between mathematical modeling ability and MHoM. The correlation coefficient obtained is 0.349, with a low correlation level. The correlation coefficient (r) = 0.349 so the coefficient of determination (D) = r^2×100% = $(0{,}349)^2$ ×100% = 12.18%. This means that the magnitude of the relationship between mathematical modeling abilities and students' mathematical habits of mind is 12.18%.

Meanwhile, the results of the correlation test between mathematical modeling abilities and EMA, it is known that the value of Sig. for the correlation test of students' mathematical modeling ability and EMA is 0.005. If the value of Sig. = 0.005 < α = 0.05, then H_0 is rejected at the significance level α = 0.05. This means that there is a significant relationship between mathematical modeling ability and EMA. The correlation coefficient obtained is 0.462, with a low correlation level. The correlation coefficient (r) = 0.462 so the coefficient of determination (D) = r^2×100% = $(0.462)^2$×100% = 21.34%. This means that the magnitude of the relationship between mathematical modeling abilities and students' early mathematical abilities is 21.34%.

Furthermore, the results of the multiple correlation test, it is known that the value of Sig. for the correlation test of students' mathematical modeling ability, MHoM, and EMA is 0.002. Sig. = 0.002 < α = 0.05, so H_0 is rejected at a significance level of α = 0.05. This means that there is a significant relationship between mathematical modeling ability, MHoM, and EMA. The correlation coefficient obtained is 0.559, with a low correlation level. The correlation coefficient

(r) = 0.559 so the coefficient of determination (D) = r^2×100%= $(0.559)^2$×100% = 31.2%. This means that the magnitude of the relationship between mathematical modeling abilities, mathematical habits of mind, and students' early mathematical abilities is 31.2%.

Table 8. Regression Test Results of Mathematical Modeling Ability, MHoM, and EMA

Model	Unstandardized Coefficients	t	Sig.
(Constant)	-214,495	-3,147	0,003
MHoM Score	1,570	2,172	0,037
EMA Value	2,241	3,044	0,005

Based on Table 8 it is known that a = -214.495; b_1 = 1.570 and b_2 = 2.241. So the relationship between mathematical habits of mind (X_1) and early mathematical abilities (X_2) to students' mathematical modeling abilities (Y) can be expressed in the regression equation:

$$\hat{Y} = -214.495 + 1.570X_1 + 2.241X_2$$

The values of b_1 = 1.570 and b_2 = 2.241 mean that if mathematical habits of mind and early mathematical ability increase by 1 score, then the average student's mathematical modeling ability increases by 1.570 and 2.241. In addition, it is known from Table 11 that the value of Sig. to test the significance of the coefficient a in the regression equation between students' mathematical modeling ability, MHoM, and EMA is 0.003. Sig. = 0.003 < α = 0.05, so H_0 is rejected at a significance level of α = 0.05. This means that the coefficient a = -214.495 in the regression equation that has been obtained is significant. While the values of Sig. to test the significance of the coefficients b_1 and b_2 in the regression equation obtained are 0.037 and 0.005. The two Sig values. are each less than α = 0.05, then H_0 is rejected at the significance level α = 0.05. Therefore it can be said that mathematical habits of mind and early mathematical abilities have a positive effect on students' mathematical modeling abilities. These results also prove that the description in Table 5 is correct, that is, the higher the mathematical habits of mind group and the early mathematical ability, the higher the level of mathematical modeling ability. This is also supported by the research results of Jerau et al. (2021), which say that students with high mathematical habits of mind are very capable of mastering the components of communication, mathematics, reasoning, and argumentation, as well as formulating and solving problems.

Therefore, it is hoped that students will have good thinking habits and get meaningful learning when studying mathematics so that their mathematical modeling skills are at a high level in the field of mathematics itself and in other broader fields, such as when solving everyday life problems. It is very important, in this era of rapid technological growth, that we prepare students to become adaptive and creative problem solvers (Pei et al., 2018).

Besides that, teachers need to develop their own abilities to prepare themselves to guide students. Teachers need to develop their own abilities to prepare themselves to guide students. Teacher education needs to be closely linked to the mathematics being taught, and even pedagogical courses need to include knowledge related to mathematics, specifically focusing on knowledge of teaching and learning mathematics (Hoover et al., 2016).

D. CONCLUSION AND SUGGESTIONS

The conclusion based on the described research results and discussion is that mathematical habits of mind and early mathematical abilities have a positive effect on the mathematical modeling skills of students. The level of mathematical modeling skill increases with the mathematical habits of mind group and early mathematical ability. If both mathematical habits of mind and early mathematical ability increase by one point, students' average modeling ability increases by 1.570 and 2.241 points, respectively. The extent of the relationship between mathematical modeling abilities, mathematical habits of mind, and students' early mathematical abilities, expressed as a percentage, is 31.2%. This can serve as a suggestion to high school instructors that mathematical modeling skills, mathematical habits of mind, and early mathematical skills are the focus of mathematics education in school and must be strengthened. In addition, this study can serve as a reference for future research on mathematical modeling skills, mathematical habits of mind, and early mathematical skills.

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