Relationships of metacognition and learning time to mathematics achievement-PISA 2018 findings in Indonesia

**F Y Anggraheni1,\*and Kismiantini2**

1Graduate School of Mathematics Education, Universitas Negeri Yogyakarta, Jl. Colombo No. 1, Sleman, Yogyakarta 55281, Indonesia

2Departement of Statistics, Universitas Negeri Yogyakarta, Jl. Colombo No. 1, Sleman, Yogyakarta 55281, Indonesia

\*[anggrahenify94@gmail.com](mailto:anggrahenify94@gmail.com)

**Abstract.** Prior studies showed that both girls and boys typically use their metacognitive skills in learning. The aim of this study is to examine the aspects measuring the students’ mathematical achievement in Indonesia. By applying multilevel analysis to the Programme for International Student Assesment (PISA) 2018 data for Indonesia, this study showed that gender, index of economic social and cultural status (ESCS), metacognition, and learning time are student-level explanatory variables that influence the students’ mathematics achievement. The findings showed that ESCS, metacognition, and learning time had positive relationships with the mathematics achievement, while gender had a negative. Higher ESCS, higher metacognition and higher learning time suggested higher achievement in mathematics, where girls were more prevalent that boys. The interaction between the ESCS (student-level) and stratio (school-level) was significant effected to mathematics achievement. It determined that gender, ESCS, metacognition, learning time, and interaction between ESCS and stratio highlighted most of the variance in students’ mathematical achievement.

1. **Introduction**

Student achievement is one element most applied to measure a school practice [1]. This achievement is calculated by an assessment that is adjusted to the target. The Programme for International Student Assessment (PISA) measure 15-year-old’s ability to use their reading, mathematics, and science. This program is a collaborative program of the Organization for Economic Cooperation and Development (OECD) countries that tests students aged 15 years-old or near the end of informal school education [2]. It then considers applying to the students in grades 7 or higher so that it can be useful in preparing to meet current social knowledge requirements [3]. The PISA assessment began in 2000 with an assessment system conducted every three years to appraise aspects of literacy in reading, mathematics, and science [4]. In 2001, Indonesia early accepted a part in PISA [5].

Mathematics achievement is one aspect used as an assessment. In PISA, mathematical measurements carried out by examining individuals’ ability to define, utilize, and understand mathematics in various situations [6]. This includes mathematical reasoning and how to interpret, illustrate and predict aspects using concepts, methods, obviousness and mathematical tools. The PISA 2018 shows a low level for Indonesia. Indonesia has reached an average of 28% compared to OECD 76%, so Indonesia is below than the average [7]. Supporting mathematics achievement, steps taken to find a cause that will impact [8]. In educational studies, the total sample sizes are combined with a sample of students from different classes or several classes [9]. Individuals in a group conceptualized as a hierarchical system of people in this case nested in schools [10]. Then those factors were examined from the individual-level to the school-level.

Many studies analyze effective gender forms in student’s mathematical achievements whose appearances are equally questionable [11]. The argument remains in the gender of male and female that has varied appears depending on the estimate, in several studies showing that gender influences mathematical achievement [11][12] and in other studies addressing gender is not significant [13]. ESCS is a student-level composite variable on economic, social, and cultural status [14], which influences mathematics achievement [11][15][16]. Metacognition is one aspect assessed in the PISA data divided into three UNDREM (understanding and remembering), METASUM (summarizing), and METASPAM (assess credibility) affect mathematical literacy [16]. The principal aspects of learning and applying characters are one of the power because interminable periods learned will not develop the most powerful achievements and limited terms [17].

Besides the reason for the student level, a school level also contains school type, school size, and student-to-teacher ratio (Stratio). The school variables were determined by pupil variables. The variation in performance in public and private schools were measured by the economic status of school students (ESCS) [15]. Another variable is the size of the school, which may be of interest to students [1]. School size is the number of students at the 15 years old who receive a school [11]. Stratio variable is the student-teacher ratio is the number of students attending school divided by the number of teachers in the school where stratio was used as proxy for class sizes [1]. This research examined factors that influence the mathematics pretension as seen from the explanatory variables in the level of student (gender, ESCS, metacognition and learning time) and school level (school type, school size, and stratio). The data taken from PISA 2018 Indonesia aims to answer the research in the form of factors that predict mathematical performance of students with statistically significant and which predictors are the strongest.

1. **Method**

This study used PISA 2018 Indonesia. The multilevel modeling (MLM) was used to analyze student and school level with different explanatory variables. It carries out the examination with mathematical literacy performance as a dependent variable with restricted maximum likelihood estimation. Implementing PISA as an international program of comprehensive and rigorous student performance time assessment and collecting data on students, families, and institutional factors that can help performance differences [6]. The purpose of PISA is not to create social inequalities between countries, but as a references to support schools and policymakers in their further development by looking at the different countries [3].

1. *Participants and Sampling*

The sampling procedure in PISA data was carried out in two stages. The first stage chooses a presentative sample from 150 schools, taking into account factors such as location (state or province and whether schools are in rural or urban areas). Then, in the second stage about 42 students aged 15 years selected from each school to participate in the assessment and most countries ranked between 4000 and 8000 students [3][18]. In Indonesia, the data used in PISA were 12,098 students from 397 schools. After removing missing data in the selected variables of interest, the comprised data were 9,991 students with 397 schools.

1. *Data Analysis*

Student-level variable (level 1) and school-level variable (level-2) arranged for each country in the PISA data [19]. The sample design used in school observations (cluster) is the same as other school observations [20]. The Multilevel analysis detects nested data where the students in this study are nested in schools, so that the predictor variables can be determined at each level [21]. Multilevel modeling is a general term used to test relationships between variables measured at different levels of stratify data structures [10]. Multilevel modeling allows researchers to investigate the nature of inter-group variability and the effects of group-level characteristics on individuals [22]. In this study, level 1 consisted gender, ESCS, metacognition, and learning time than level 2 are school type, school size, and student-teacher ratio in which it was included according to their level in the model. In this study, the nlme package in R program [23] was used to analyze various multilevel models on PISA 2018 Indonesia data.

1. **Result and Discussion**

A multilevel data theory requires multilevel data to be explained by grouping in criteria, and variables can be assigned to the appropriated level [10]. The PISA scoring is adjusted to the normal distribution of an average of about 500 score points and standard deviation of 100 point scores, which is the difference of one-point on the PISA scale according to the effect size (cohen’s d) 0.01 and variance of 10 points [24]. The standardized explanatory scaled of PISA for OECD countries with an average of 0 and standard deviation 1, which the assessment is centered on average according to the design of MLwiN program [25].

1. *Step 1: model without an explanatory variable (null model)*

The simplest linear model with the school effect remains represented by equation (1) in this model, the average student expected is 397.89 in the mathematics test. However, this model acts considering missing data on each explanatory variable and thus ignores the effect of explanatory variables varying in different schools. The null random effect model (2) allows for calculated school effects on mathematics achievement to provide information on the number of intermediate and variance in school. MathAchij shows the mathematical achievement of students i in school j, β0 shows the average intercept, eij shows the student level residue, and the value in parentheses is a standard error value (SE).

 (1)

u0j shows the variance in school j around the intercepts on the average intercept. The predicted equation (1) is given below,

 (2)

where represents the level-two variance estimate and represents the level-one variance estimate.

The null model without explanatory variables in equation (2) used to detect significant differences between schools. The likelihood ratio test (LRT) performed to compare random zero effects for the fixed effect models applied. The LRT Statistic defines as χ2 = [-2logLReducedModel]-[-2logLFullModel] [9]. Based on equation (2), it has obtained that χ2 = 2(-54,029.94)]-[-2(-57,788.66)] = 7,519.32 refers to the LRT statistic with corresponding to the chi-square distribution and three free degree of freedom (χ2(3) = 7,519.32 > 16.27). The mathematics achievement variance between schools is (*p* < 0.01) with standard deviations of 59.10 and within schools is (p < 0.01) with standard deviations of 50.46. Substituted these values into the equation  [22], then the estimatedICC = 3,493/(3,493+2,546) = 0.58. Therefore, 58% attributed to achievement between schools and 42% in school. Substituted ICC value into the eqution [9], then the estimated 14.98 > 2.0 is confirmed that the multilevel model is suitable to use.

1. *Step 2: adding student-level explanatory variables to the random intercept model*

Explanatory variables for student-level in equation (3) were the data listed in table 1 incuded gender, ESCS, metacognition, and learning time. Then, these explanatory variables were used to analyze the students’ mathematical achievements.

 (3)

where represents the level-two variance estimate and represents the level-one variance estimate.

Results using Equation (3) show that the ESCS is a significant explanatory variable influencing mathematical achievement (b = 4.37, SE = 0.58, *p* < 0.001). Since the coefficient estimate is positive, it means that the higher the ESCS level then the higher the mathematics achievement [26]. The gender has a significant relationship to mathematical achievement (b = -0.11, SE = 1.04, *p* < 0.05). The negative coefficient for gender indicated that girls outperformed than boys in mathematics actievement. This significant result is contrary to Chen’s study that student gender does not influence appreciable achievement in mathematics [13]. The student metacognition has a significant relationship to mathematical achievement (b = 21.63, SE = 0.75, *p* < 0.001). The positive coefficient of student metacognition in line with Muszynski’s that higher metacognition yields higher student mathematics achievement [27]. The learning time has a significant relation to the mathematics achievement with the estimated coefficient of b = 0.02 (SE = 0.00, *p* < 0.001). The learning time has a positive influence on mathematics achievement, which is consistent with Erikson and Ryve’s research that student achievement is influenced by how teachers more spend less time effectively in learning [17]. The statement revealed that effective learning does not need part-time, while the least amount time of spent on understanding will be more effective in mathematics achievement.

1. *Step 3: adding school-level explanatory variables to the model*

After checking the student-level variables and finding that many explanatory variables still exist that can be better explored for their effects on mathematical achievement. Then the next step is to identify explanatory variables at the school level. These variables include learning time, school type, and school size.

Sakellario (2017) results revealed that in most developing countries in Latin American countries, students in private schools outperformed public schools [15]. In developing countries, the public schools were more stable in performance compared to one’s private unstable[15]. In terms of school size, students from large schools in terms of student population get superior results than from small schools [28]. The teacher-student ratio (Stratio) in the Giambona and Porcu research showed a positive impact on student achievement [1].

 (4)

where represents the level-two variance estimate and represents the level-one variance estimate.

Results using equation (4) shows that the ESCS is significant explanatory variable influencing mathematical achievement (b = 4.36, SE = 0.58, *p* < 0.001). Since the coefficient estimate is positive, it means that the higher the ESCS level then the higher the mathematics achievement [26]. The gender has a significant relationship to mathematical achievement (b = -0.09, SE = 1.04, *p* < 0.05). The negative coefficient for gender indicated that girls outperformed than boys in mathematics achievement. This significant result is contraty to Chen’s study that student gender does not influence appreciable achievement in mathematics [13]. The student metacognition has a significant relationship to mathematical achievement (b = 21.62, SE = 0.75, *p* < 0.001). The positive coefficient of student metacognition in line with Muszynski’s that higher metacognition yields higher student mathematics achievement [27]. The learning time has a significant relation to the mathematics achievement with the estimated coefficient of b = 0.02 (SE = 0.00, *p* < 0.001). The learning time has a positive influence on mathematics achievement, which is consistent with Erikson and Ryve’s research that student achievement is influenced by how teachers more spend less time effectively in learning [17]. The statement revealed that effective learning does not need part-time, while the least amount of time spent on understanding will be more effective in mathematics achievement.

In the table 1 shows that the explanatory variable at the school level does not influence significant mathematics achievement. The school-type has not considerate influence mathematics achievement with the estimated coefficient of b = -1.55 (SE = 1.43, *p* = 0.23). The result was difference with Ozdemir’s analysis that school type has statistically significant associations with PISA maths scores [29]. The school-size has not significant relationship to mathematics achievement (b = 0.00, SE = 0.00, *p* = 0.34). This result of school-size was contast to Giabona and Porcu’ research that student achievement is influenced by how school size might affect student achievement [1]. The Stratio has not significant relation to the mathematics achievement with estimated coefficient of b = 0.03 (SE = 0.04, *p* = 0.52). This result of stratio was contrast to Milford, Ross and Anderson’ research that Stratio was significant for the United States and Mexico [14]. The study have shown that the three explanatory variables at the school level has not significant on mathematics performance. Similarity with Chen and Teodorovic’ research findings which indicate that students’ mathematical performance is caused more by student factors then school factors [13][8].

1. *Step 4: adding interactions between explanatory variables to the model*

Adding explanatory variables to the model allows interactions between variables. The multilevel organization theory (MOT) explains that the interaction process can occur simultaneously at the lower level (student level) and higher (school level) [30]. From twelve interactions possible from the combination of the explanatory variables of student level and school level, it has obtained one of significant interaction between ESCS and student teacher ratio (Stratio).

(5)

Results from equation (5) shows that the ESCS is significant explanatory variable influencing mathematical achievement (b = 5.13, SE = 0.67, *p* < 0.001). Since the coefficient estimate is positive, it means that the higher the ESCS level then the higher the mathematics achievement [26]. The gender has a significant relationship to mathematical achievement (b = -0.03, SE = 1.04, *p* < 0.05). The negative coefficient for gender indicated that girls outperformed than boys in mathematics activement. This significant result is contrary to Chen’s study that student gender does not influence appreciable achievement in mathematics [13]. The student metacognition has a significant relationship to mathematical achievement (b = 21.63, SE = 0.75, *p* < 0.001). The positive coefficient of student metacognition in line with Muszynski’s that higher metacognition yields higher student mathematics achievement [27]. The learning time has a significant relation to the mathematics achievement with the estimated coefficient of b = 0.02 (SE = 0.00, *p* < 0.001). The learning time has a positive influence on mathematics achievement, which is consistent with Erikson and Ryve’s research that student achievement is influenced by how teachers more spend less time effectively in learning [17]. The statement revealed that effective learning does not need part-time, while the least amount of time spent on understanding will be more effective in mathematics achievement.

In the table 1 shows that the explanatory variable at the school level does not influence significant mathematics achievement. The school-type has not considerate influence mathematics achievement with the estimated coefficient of b = -1.54 (SE = 0.28, *p* = 0.28). The result was difference with Ozdemir’s analysis that school type has statistically significant associations with PISA maths scores [29]. The school-size has not significant relationship to mathematics achievement (b = 0.00, SE = 0.00, *p* = 0.32). This result of school-size was contast to Giabona and Porcu’ research that student achievement is influenced by how school size might affect student achievement [1]. The Stratio has not significant relation to the mathematics achievement with estimated coefficient of b = -0.03 (SE = 0.04, *p* = 0.42). This result of stratio was contrast to Milford, Ross and Anderson’ research that Stratio was significant for the United States and Mexico [14]. The study have shown that the three explanatory variables at the school level has not significant on mathematics performance.

Based on equation (5), the interaction between ESCS and student-teacher ratio (Stratio) has a significant relation to mathematics achievement (b = -0.00, SE = 0.00, *p* < 0.05). The negative coefficient means that the interaction between ESCS and student-teacher ratio (Stratio) causes a decrease in mathematical performance. This result is contrary to Peugh’s research that the interaction between ESCS and student-teacher ratio (Stratio) causes an increases in mathematical performance [9].

**Table 1**. Summary of Multilevel Models for Indonesia in PISA 2018

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameters** | **Unconditional** | **Level-1** | **Level-2** | **Interaction** |
| **b (SE)** | **b (SE)** | **b (SE)** | **b (SE)** |
| **Fixed** |  |  |  |  |
| Intercept | 397.89 (3.04)\*\*\* | 411.95 (3.31)\*\*\* | 414.71 (5.40)\*\*\* | 415.80 (5.43)\*\*\* |
| *Level-1 Student* |  |  |  |  |
| Gender | - | -0.11 (1.04)\* | -0.09 (1.04)\* | -0.03 (1.04)\* |
| ESCS | - | 4.37 (0.58)\*\*\* | 4.36 (0.58)\*\*\* | 5.13 (0.67)\*\*\* |
| Metacognition | - | 21.63 (0.75)\*\*\* | 21.62 (0.75)\*\*\* | 21.63 (0.75)\*\*\* |
| Learning Time | - | 0.02 (0.00)\*\*\* | 0.02 (0.00)\*\*\* | 0.02 (0.00)\*\*\* |
| *Level-2 School* |  |  |  |  |
| School Type | - | - | -1.55 (1.43) | -1.54 (0.28) |
| School Size | - | - | 0.00 (0.00) | 0.00 (0.00) |
| Stratio | - | - | -0.03 (0.04) | -0.03 (0.04) |
| ESCS-Stratio | - | - | - | -0.00 (0.00)\* |
| **Random** |  |  |  |  |
| Variance in achievement between schools | 3,493 | 2,692 | 2,686 | - |
| Variance in achievement within schools | 2,546 | 2,345 | 2,345 | - |

Parameter estimate standard error specified in parentheses

\*\*\**p* < 0.001, \*\**p* < 0.01, \**p* < 0.05

1. *The best model based on the AIC and BIC*

All four different models were developed to assess better model fit. Table 2 provides the Akaike information criterion (AIC) and Bayesian information criterion (BIC) for each multilevel model.

**Table 2**. Model Comparison

|  |  |  |
| --- | --- | --- |
| **Random Intercept** | **AIC** | **BIC** |
| Model without explanatory variable | 108,061.8 | 108,083.5 |
| Adding student-level explanatory variables | 107,181.3 | 107,231.8 |
| Adding school-level explanatory variables | 107,216.7 | 107,288.8 |
| Adding interactions between explanatory variables | 107,224.6 | 107,303.9 |

Table 2 shows adding student-level explanatory variables (model 2) has the lowest AIC and BIC values. The second model includes gender, ESCS, metacognition, and learning time explanatory variables. The PISA 2018 Indonesia findings revealed that the effects of explanatory variables at the student level are more influential on mathematics performance than at the school level. This result is similar to the research carried out by Chen and Teodorovic which indicates that students’ mathematical performance is caused more by student factors than school factors [13][8].

1. **Conclusion**

In this study, the factors at student level and school level which influence student mathematics achievement in Indonesia were explored. The results of the multilevel analysis revealed that significant variables at the student-level influenced the mathematics achievement of students in Indonesia whereas variables at the school-level were not significant. The interactions between ESCS and stratio had a significant on a student’s mathematics achievement. The ESCS, metacognition and learning time had positive relationship to students’ mathematical achievement, where girls performed better than boys. The school level varables found that the school type, school size and stratio did not significantly influence the students’ mathematics achievement.

Overall, the analysis obtained results in a finding that Indonesia education policymakers should consider student gender, ESCS, student metacognition and learning time that can affect students’ mathematics achievement. This study also explains the factors predicted to influence the mathematics achievements of students in Indonesia so that multilevel analysis can contribute significantly to knowledge formation and additional literature in educational policy making.

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