PISA 2018: Non-Cognitive Factors and School Characteristics Towards Mathematics Achievement in Indonesia

A W Krisnamurti1 and Kismiantini2

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

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

1andhikawildan@gmail.com

**Abstract**. Researchers found that non-cognitive factors and the school of students can affect the academic achievement of students during the educational phase. The goal of this study is to examine the relationship between non-cognitive factors and school characteristics to mathematics achievement. Data used in this study were taken from 9,262 students in 334 schools in Indonesia that participated in the Programme for International Student Assessment (PISA) 2018. At the student level, the non-cognitive aspects include life satisfaction, positive feelings, and negative feelings; while at the school level, the independent variables include school categories (public/private), distance considerations in the admission of new students, and school environment. Multilevel analyses showed that feelings of happiness and anxiety at the student level had positive relationship with mathematics achievement, and students attending public school (at the school level) were reported to have a better mathematics achievement.

1. Introduction

Data source that many people know about international measurement is the Program for International Student Assessment (PISA) conducted by the Organization for Economic Co-operation and Development. This three-year research measures abilities in reading, science, and mathematics in several countries including Indonesia. There is no country participating in PISA 2018 in which all students have gained basic skills in mathematics, science and reading [12]s. Only 28% of Indonesian students can reach level two or more (average OECD 76%) and only 1% reach level five or more [15]. The low achievement of Indonesian students needs to be examined with influential factors in order to increase the subsequent achievements. Researchers found that some student-related factors, like as non-cognitive aspects, can influence their academic achievements. Several studies have shown that students’ affective can be a factor [1,4,5,6,11,19]. In addition, school can also impact on educational progress of the students. Previous PISA studies revealed that different schools yield different students’ achievement [7,9,10]. Previous studies related to the affective characteristics of students and school aspects toward students’ performance using PISA dataset with multilevel analysis are considered rare in Indonesia [19]. The report was usually focused more on the mean score and percentages of students’ performances. This study examines the relationship of a collection of independent variables of non-cognitive factors (life satisfaction, positive feelings, negative feelings) and school characteristics (public or private, consideration of distance in student admission, and school location) to a single dependent variable of mathematics achievement.

1. Literature Review

Several factors can influence the achievement of mathematics scores from both the students themselves and from their school. The PISA 2018 questionnaires aimed to interpret valid cognitive and non-cognitive scores [16]. The questionnaire contained several constructs including metacognitive and non-cognitive, student backgrounds, school teaching and learning activities, and school or government policies. The results of the questionnaire on life satisfaction, positive feelings and negative feelings were selected at the student level. Whereas the results of the school background questionnaire were selected for the school level in relation to the school category (public or private), the policy of considering distance from the admission of new students (never, sometimes, always), and where the school environment was (a village, a small town, a town, a city, a big city) located.

## Life Satisfaction, Positive Feelings, and Negative Feelings

Life satisfaction, positive feelings and negative feelings are three factors in the 2018 PISA research that are one of the dimensions of student well-being [16]. This aspect of the life satisfaction score is zero to then with zero showing unsatisfied and ten indicating very satisfied. Then negative and positive feelings are part of student well being in affective or emotional pieces. This score has a scale ranging from one to four, which means how often students feel it for never, rarely, sometimes, and always. In the questionnaire, positive feelings in question include happy, lively, proud, joyful and cheerful. While negative feelings are scared, miserable, afraid and sad. Scores from this aspect are one to four in scale, with one means never and four means always.

The non-cognitive aspect of life satisfaction was also reviewed at PISA 2015. In the study, the effect of life satisfaction on students’s ability in schools has been classified as low [14]. This means students with high and low scores have the same standard of living satisfaction in most countries. These students’ life satisfaction differs in one country or among countries, one of which is influenced by the school environment [13]. In Indonesia, students’ average life satisfaction is 7.47 which is higher than the OECD average of 7.04 [18].

Several studies have shown that affective aspects can be a factor in the students' academic achievement. Study revealed that based on the results of PISA 2015, the greater the anxiety of students, the greater the motivation they have [6]. This motivation can lead to better academic performance efforts. While mathematics anxiety itself has a negative effect on the achievement of mathematics scores [1,11]. The higher the students’ level of mathematics anxiety, the lower the mathematics scores achieved. On average anxiety in mathematics affects the reduction of 34 points in mathematics scores. Similar affective aspects such as positive and negative emotions also affect mathematics ability. Researcher found that positive emotions (enjoyment and pride) had a positive effect on mathematics achievement. While negative emotions (anger, anxiety, shame, boredom, hopelessness) have a negative influence on mathematics achievement [20]. Other research found that positive emotions encourage students to use various cognitive and metacognitive strategies [4]. In addition to emotions, the attitudes that affect academic achievement also have affective aspects. Another study found that the positive attitude of mathematics supports the achievement of mathematics within the limit material [5].

## School Background

Schools can also be a factor in the academic achievement of the students. The 2009 PISA study informed that overall student performance at country level was attributed around 40 percent variance due to differences in students' ability between schools [9]. Differences in school backgrounds, such as school welfare, where the school (urban/rural) is located, and existing policies can be several factors [7, 9, 10].

1. Aim and Research Questions

The non-cognitive aspects of students and school background can affect student academic achievement from some literatures shown. Using the student level and school level variables, the researcher aims to use multilevel modeling to find out the mathematics abilities of Indonesian students in PISA 2018. Some questions to answer from the research are as follows.

1. How big is the variance in students' math scores at between school and within-school levels?
2. Which factor is statistically significant for predicting math scores?
3. Which factor is the strongest predictor for explaining mathematics score in the final multilevel model?
4. How big is the total variance explained by the predictor variables in the final multilevel model?
5. Method

## PISA Design

PISA is a triennial survey of 15-year-old students worldwide, measuring the extent to which students have gained important knowledge and skills to participate in socio-economic life [17]. Three important aspects measured are the reading, science and mathematics ability. In 2018 reading ability became a major aspect. All aspects are measured by computer. In addition, also questionnaires were given to students and principals [18].

## Data Sources and Sampling

The data used is the result of PISA 2018 which is available for download on the official website of the OECD. Aproximately 600,000 students completed the assessment representing 32 million 15-year-old students in 79 countries and economies. These students may participate in various programs or levels of education in a country. Indonesian students could have been in grade 9 or 10, with 12,098 students in 397 schools represented. In this study, Indonesian students took complete data, which amounts to 9,262 in 334 schools.

The PISA survey uses a complex methodology [8]. The PISA does not use simple random samples for students. This study chose a two stages sample starting with the school and then with the students. The PISA also uses the imputation method presented in plausible values ​​to report students' abilities.

## Data Analysis

Multilevel modeling of two levels using PISA 2018 data was analyzed using the nlme package in R’s open source program [22]. This study used the random intercepts model in the analysis. The predictor variables at the student level include life satisfaction (LS), happy (HPY), lively (LVL), proud (PRD), joyful (JOY), and cheerful (CRF), scared (SCR), miserable (MSR), afraid (AFR), and sad (SAD). The school level predictor variables are school category (SC), consideration of distance in the admission of new students (DTC) and the school environment located (SL). All variables are treated as continuous variables to give greater insight.

1. Results

In this research, multilevel modeling is carried out in stages [2]. The results of PISA are reported in a scale. The average reading, science and mathematics scores are 500 with a standard deviation of 100 [16]. Mathematics scores consist of ten plausible values ​​which are searched for on average so that each Indonesian student receives a mathematics score. Table 1 presents descriptive statistics before proceeding with the multilevel modeling analysis.

The average mathematics score in Indonesia is 406.75 which is actually below the OECD average. Indonesian students sometimes feel the positive feelings, and rarely feel the negative feelings on average. The students have also been moderately satisfied with their lives. For school aspects, mostly are public schools in a small town which sometimes considered the students’ residence in a particular area.

**Table 1.** Descriptive Statistics

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **Mean** | **Standar Deviation** | **Median** |
| MathScore | 406.75 | 78.9 | 400.92 |
| HPY | 3.46 | 0.65 | 4 |
| LVL | 3.47 | 0.64 | 4 |
| PRD | 3.21 | 0.68 | 3 |
| JOY | 3.49 | 0.63 | 4 |
| CRF | 3.53 | 0.63 | 4 |
| LS | 7.37 | 2.42 | 8 |
| SCR | 2.68 | 0.65 | 3 |
| MSR | 1.95 | 0.83 | 2 |
| AFR | 2.69 | 0.68 | 3 |
| SAD | 2.57 | 0.68 | 3 |
| SC | 0.71 | 0.45 | 1 |
| DTC | 2.42 | 0.73 | 3 |
| SL | 2.78 | 1.19 | 3 |

## Step 1: Model Without Predictors (Null Model)

The result of the model without the predictors is in equation (1) where the values ​​in parentheses are the standard error. From this model, it is obtained that the average student's math score is 395.236. The estimated variance between schools is 3,599 and within schools is 2,585. The equation for the estimated empty model is given as follows.

$\hat{MathScore}\_{ij}=395.236(3.351)$ (1)

where the paranthesial value indicates the standard error of the corresponding estimate.

In order to responds to the need for multilevel modeling existing data, the intraclass correlation (ICC) and design effect (DE) values ​​are required [21].

$$ICC=\frac{3,599 }{3,599 +2,585}=0.582$$

$$DE=1+\left[\left(\frac{9,262}{334}-1\right)×ICC\right]=16.557$$

The ICC value of 0.582 can be interpreted that 58.2% of the variance is explained by differences in schools and by 41.8% is explained by differences in students at the school level. The minimum ICC requirement is around 0.05 to 0.2, sufficient to use multilevel models [20]. The ICC value of 0.582 thus states that data should be analyzed using multilevel modeling. Then the size of DE greater than 2.0 indicates the need for multilevel modeling analysis [20]. The DE value of 16.557 represents for the data to be analyzed using multilevel modeling.

## Step 2: Model with Student Level Predictors

Equation (2) is the result of student-level multilevel modeling using predictors, namely HPY, LVL, PRD, JOY, CRF, LS, SCR, MSR, AFR, and SAD. It was found from this model that the average mathematics score of students was 407.683. In addition, the variance between schools is 3,495 and the variance within schools is 2,553.

$\hat{MathScore}\_{ij}=407.683\left(5.945\right)+7.136\left(5.945\right)BHG\_{ij}-3.039\left(1.013\right)SGT\_{ij}-5.151\left(0.920\right)BGA\_{ij}-0.786\left(1.218\right)GBR\_{ij}-1.273\left(1.154\right)CRA\_{ij}-0.556\left(0.238\right)KH\_{ij}+4.976\left(0.985\right)CMS\_{ij}-2.899\left(0.734\right)SSR\_{ij}-0.181\left(0.9531\right)KTR\_{ij}-2.252\left(0.896\right)SDH\_{ij}$ (2)

Seven out of ten variables are significant predictors (*p-value < 0.05*) and the rest are not. The seven predictors are HPY, LVL, PRD, LS, SCR, MSR, SAD. From seven variables, only two had positive effect, namely HPY and SCR. This means that if the student feels happier and more scared, the math score will be higher. While the other five significant predictor variables, namely the frequency of feeling lively, proud, miserable, sad, and life satisfaction, all have negative effects.

Adding predictor variables resulted the variances between schools and within schools decreasing from 3,599 to 3,495 and 2,585 to 2,553, respectively. Aproximately 2.2% of the total variance (1.2% at the student level and 2.9% at the school level) is explained by the addition of the student level predictor variables in this model.

## Step 3: Model with Addition of School Level Predictors

The second step is to build a model with school-level predictors namely SC, DTC, and SL as written in equation (3). It was found from this model that the average mathematics score of students was 335.586. In addition, the variance between schools is 2,573 and the variance within schools is 2,553.

$\hat{MathScore}\_{ij}=335.586\left(13.064\right)+7.154\left(1.118\right)BHG\_{ij}-3.074\left(1.013\right)SGT\_{ij}-5.177\left(0.919\right)BGA\_{ij}-0.813\left(1.218\right)GBR\_{ij}-1.245\left(1.153\right)CRA\_{ij}-0.564\left(0.238\right)KH\_{ij}+4.958\left(0.985\right)CMS\_{ij}-2.848\left(0.734\right)SSR\_{ij}-0.220\left(0.9531\right)KTR\_{ij}-2.243\left(0.896\right)SDH\_{ij}+25.602\left(5.986\right)KS\_{ij}-2.824\left(3.855\right)JRK\_{ij}+23.916\left(2.353\right)LKN\_{ij}$ (3)

There were only two statistically significant variables from the school level, namely SC and SL. In other words, there are differences between public and private school students in the math scores. The public school students have higher scores than the students from private school. Then, students who are in rural schools will get lower scores related to the school environment. While the DTC variable is not significant, this means that consideration of the school’s distance from the student residence when new students are admitted does not affect the mathematics scores at the school.

The addition of these school-level predictor variables caused variance between school and within-school to decrease from 3,495 to 2,573, respectively. This reduction means that the variance of students' mathematics scores was explained by the addition of school-level predictor variables. About 26.4% of the variance between schools was explained by the addition of student level predictor variables in this model.

## Interpretation of the Final Model

Among three models which have been analyzed, the final model was the best model to predict students’ mathematics score (AIC = 100,040 and BIC = 100,154). From the addition of predictors at the student and school levels, the final model in multilevel modeling explains about 17% of the variance in mathematics scores with a change in total variance of 6,184 reduced to 5,126. This model explains 28.5% difference in school level and 1.2% difference in student level. A summary of the results of the analysis can be seen in Table 2.

This final model shows that there are nine significant variables, namely seven from the student level and two from the school level. At the student level we can interpret as those on the previous model. The school level variables’ influence is much stronger than at the student level. This can be seen in the coefficient of the school category and the school environment located. Thus the mathematics scores of students will be more influenced by the categories and school environment located compared to their daily personal feelings.

1. Discussion

From the results of the study to answer the question "how big is the variance on students' mathematics scores at between school and within-school levels?", aproximately 58.2% of the variance in mathematics scores is explained by differences in schools and by 41.8% is explained by differences in students within-school. From these findings it can be explained that the Indonesian students’ mathematics achievement in PISA 2018 are more influenced by factors at the school level than at the student level. These results are similar to study that reveal the influence of schools on students' mathematics scores [3].

**Table 2.** Result Summary

|  |  |  |  |
| --- | --- | --- | --- |
|  | Model Without Predictors (SE) | Level 1 Predictor Model (SE) | Final Model (SE) |
| HPY | - | 7.136 (5.945) \*\*\* | 7.154 (1.118) \*\*\* |
| LVL | - | -3.039 (1.013) \*\* | -3.074 (1.013) \*\* |
| PRD | - | -5.151 (0.920) \*\*\* | -5.177 (0.919) \*\*\* |
| JOY | - | -0.786 (1.218) | -0.813 (1.218) |
| CRF | - | -1.273 (1.154) | -1.245 (1.153) |
| LS | - | -0.556 (0.238) \* | -0.564 (0.238) \* |
| SCR | - | 4.976 (0.985) \*\*\* | 4.958 (0.985) \*\*\* |
| MSR | - | -2.899 (0.734) \*\*\* | -2.848 (0.734) \*\*\* |
| AFR | - | -0.181 (0.953) | -0.220 (0.953) |
| SAD | - | -2.252 (0.896) \* | -2.243 (0.896) \* |
| SC | - | - | 25.602 (5.986) \*\*\* |
| DTC | - | - | -2.824 (3.855) |
| SL | - | - | 23.916 (2.353) \*\*\* |
| Between school Variance | 3,599 | 3,495 | 2,573 |
| Within-school variance | 2,585 | 2,553 | 2,553 |
| Variations explained |  |  |  |
| School Level | - | 0.029 | 0.264 |
| Student level | - | 0.012 | - |
| Total | - | 0.022 | .152 |
| AIC | 100,246 | 100,135 | 100,040 |
| BIC | 100,267 | 100,227 | 100,154 |

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

Multilevel modeling results also answered the second and third questions namely "which factors are statistically significant for predicting mathematics scores?" and "which factors are the strongest predictors for explaining mathematics scores in the final multilevel model". The significant factors for student level include life satisfaction, happy, lively, prude, scared, miserable and sad. The significant factors for the school level are the school category and school environment located. Then out of the nine significant predictors, the biggest influence was found on the school level variable, namely the school category followed by the school environment located. These results are similar to studies that reveal that the school background can influence the student performance [9, 10].

From this study it is informed that non-cognitive aspects can affect the achievement of students' mathematics scores. Students who feel happier and more scared in their lives are getting higher math scores. Whereas, for those who are more satisfied in life, joyful, proud, miserable, and sad will get lower mathematics scores.

The school level variables were significant influences than the non-cognitive aspects of students. The different types of schools, namely public and private, most significantly influence to the achievement of mathematics scores. Students in public schools score higher than those in private schools. The school environment located variable is significant as the school category variable. Students whose schools are located in urban areas get a higher score. Thus, students in Indonesia whose schools are located in cities and public schools will have a much higher math score. These results support the findings from study that have been conducted [7].

The final question in this study is "how big is the total variance explained by the predictor variables in the final multilevel model?". From multilevel modeling it is found that the final model explains about 17% of the mathematics score variance. In more detail, this model explains 28.5% and 1.2% differences at the school level and student level, respectively. Thus, 83% of the variance in mathematics scores has not been explained by this model. This can be used as further research to obtain predictors that can explain most variance in mathematics scores.

1. Conclusion

This study provides an overview several significant factors of the achievement of Indonesian students’ mathematics scores at PISA 2018. Results of multilevel modeling reveal that schools have a greater influence on mathematics scores compared to the non-cognitive aspects of students. The categories of schools and the environment in which schools are located are two strong influences in the final multilevel model. The life satisfaction, positive feelings, and negative feelings are not all significant. A significant factor with a positive relationship to mathematics score includes happy and scared. While the factors that are significant and have a negative relationship to mathematics score are life satisfaction, lively, proud, miserable, and sad. This study revealed only 17% of variance in mathematics score so further research can be done to explain more.

The results of this study can be used for policy makers, educational stakeholders, educators, and parents to pay attention to the non-cognitive aspects of students as well as equalizing the quality of schools in Indonesia. This research is limited to some of those factors selected in PISA 2018. However, it is expected to contribute to research related to PISA in Indonesia.

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