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Teacher Competencies, The Shortage of School Resources and Mathematics Achievement Based on PISA 2018 Indonesia

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Abstract

Investigating the low mathematics scores of Indonesian students on the PISA assessment can be done by examining the influence of measured predictors, including teacher competence and school resources that have not attracted the attention of Indonesian mathematics education researchers. The research focused on the effect of teacher competencies and the shortage of school resources on students' mathematics achievement. Secondary data were retrieved from the official PISA website, involving 9,721 students aged 13-15 years from 332 schools after deleting the missing data. All students and schools were recruited using a stratified-two stage sample design and did not meet the exclusion criteria. Multilevel analysis was used to determine the significance of predictors of interest on students' mathematics achievement. The analysis showed that adaptive teaching, teacher emotional support and teacher enthusiasm contributed to increase students' mathematics achievement while teacher feedback and the shortage of school resources significantly decreased students' mathematics achievement. These findings can assist policymakers in setting educational priorities especially related to what teacher competencies should be developed and procurement of school resources.

Keywords: Teacher Competencies, The Shortage of School Resources, Mathematics Achievement, PISA 2018 Indonesia

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INTRODUCTION

Indonesia has participated in the PISA assessment for mathematics since 2003, which continues every three years. The mathematics scores of Indonesian students were 360 (2003), 391 (2006), 371 (2009), 375 (2012), 386 (2015), and 379 (2018) (OECD, 2019b). It is recognized that these scores are unsatisfactory. A number of research have sought to address this issue by analyzing students' ability to solve PISA-like problems (Risa et al., 2023; Zulkardi et al., 2020) and mathematical literacy content in the textbook (Setiawan et al., 2023). In addition, the development of PISA-like mathematics problems (Aini et al., 2023; Fauziah & Pandra, 2023; Mouli et al., 2023; Nusantara et al., 2021; Putri & Zulkardi, 2020; Sepriliani et al., 2022) and teaching materials (Susanta & Sumardi, 2022; Wathani et al., 2022) have been carried out, allowing teachers to use these products in learning. Experiments aimed at testing the effective learning to improve mathematical literacy have also been conducted (Angreanisita & Mastur, 2021; Fauziyah et al., 2021; Imam et al., 2020; Syafitri et al., 2021). Using PISA data, researchers focused on the psychological predictors, school context, learning supports, students's background, and parental education (Haryuniati & Suranto, 2021; Kismiantini et al., 2021). Unfortunately, mathematical literacy researchers in Indonesia still pay little attention to teacher competencies and school resources that are likely to contribute to raising students' mathematics

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achievement.

Teacher competencies are defined as abilities that describe the ideal characteristics of a teacher such as having excellent abilities, knowledge, and motivation to educate students in pursuit of better academic achievement (Fauth et al., 2019). Numerous studies have reported that teacher competencies affect learning outcomes, especially in mathematics (J. König et al., 2021; Mahartini et al., 2023; Wawan & Retnawati, 2022). This shows that teacher competencies are important to develop in order to enhance the quality of learning. In Indonesia, pedagogical knowledge is not enough as an indicator of a teacher competencies but also social skills, good personality, and professionalism (Law of the Republic of Indonesia Number 14 of 2015 concerning Teachers and Lecturers, 2005). Referring to those indicators, there are several predictors in the PISA questionnaire describing teacher competencies, namely, adaptive instruction, teacher emotional support, teacher feedback and teacher enthusiasm.

In separate studies, those predictors have been shown to enhance students' learning outcome (Wisniewski et al., 2020; Yang et al., 2021). By providing emotional support, students will feel cared for, appreciated, understood and helped, leading to a supportive and positive learning environment (An et al., 2023; Ruzek et al., 2016). Likewise, when teachers are enthusiastic in the classroom, students become motivated to learn and give their full attention to the teacher thus increasing students' engagement (L. König, 2021). In addition, when teachers conduct adaptive learning that pays attention to students' conditions and needs, they perceive that learning is an inconvenient experience so they feel comfortable (Gallagher et al., 2022). Additionally, the feedback given by teachers will be a piece of useful information to find out students' weaknesses and strengths so they know what to improve. However, feedback that explains the student's weaknesses should be expressed carefully to avoid negative emotions leading to demotivation. A positive statement that explains the student's weaknesses will be a source of motivation to continue developing competence. Not only that, feedback that demonstrates the student's strengths will increase self-efficacy because success in past experience is a source of self-efficacy that leads to higher motivation (Bandura, 1997). Nevertheless, in explaining the students' strengths, teachers should provide challenges to keep their motivation growing. Based on this explanation, it can be concluded that all predictors to explain teacher competencies are likely to improve students' achievement.

In the PISA report, it was stated that 88% of Indonesian students agreed and strongly agreed that teachers were enthusiastic when teaching the material in class (Avvisati et al., 2019). This indicates that Indonesian teachers try to establish a joyful learning environment that allows students to give their full attention to the teacher. However, it is not yet known whether teacher enthusiasm has any contribution in improving students' mathematics achievement when it is well below the OECD average. Similarly, other predictors need to be tested to see if they contribute to improving Indonesian students' mathematics achievement.

Apart from not knowing the influence of teacher competencies on students' mathematics achievement, another problem which must be addressed is the shortage of school resources. This

problem is due to the uneven distribution of teachers and material resources. In PISA 2018, school resources include human and material resources. Using material resources during teaching and learning helps students in concretizing concepts (Kul et al., 2018). Furthermore, Alacaci & Erbaş (2010) stated that the availability of school resources supported the improvement of students' learning outcome. However, a study by Akyüz (2014) found that existing school facilities had no significant impact on students' learning outcome. Because the influence of the shortage of school resources on students' mathematics achievement is still being debated, it is critical to know whether the shortage of school resources affects students' mathematics achievement in Indonesia.

Based on the literature above, it can be seen that teacher competence and shortage of school resources affect students' mathematics achievement. However, the literature discussing these two variables is still very limited. In addition, research that examines the influence of teacher competence and school resources is mostly conducted in developed countries, so there is a need for literature that examines the influence of these two variables in developing countries. Moreover, investigations using samples with mathematics scores below the OECD average such as Indonesia are limited. Obviously, different characteristics are likely to report different results. This study also complements previous literature that has examined predictors that affect the mathematics achievement of Indonesian students in the 2018 PISA assessment. Thus, this study can contribute as consideration for policymakers to develop policies that will improve Indonesian students' mathematics achievement.

METHODS

The study used secondary data from PISA 2018 obtained through the website (http://www.pisa.oecd.org). The two-stage stratified sampling technique was employed to determine participants who would take the PISA assessment (OECD, 2019a). By using the technique, PISA data consisted of data at the school level (primary sample) and the student level (secondary sample). A total of 12,098 15-years-old students and 397 schools from Indonesia voluntarily participated in PISA 2018 (OECD, 2018). Due to the occurrence of missing data in the variables of interest, the sample size that can be analyzed was 9,721 students and 332 schools.

The use of the two stratified sampling resulted in student was nested within the school. Consequently, the multilevel model is suitable to investigate the effect of level-1 predictor (teacher competencies consist of adaptive instruction, teacher emotional support, teacher feedback, and teacher enthusiasm) and level-2 predictor (shortage of school resources) on students' mathematics achievement (Cohen et al., 2007). The multilevel model began with the construction of the null model. It comprised just the dependent variable, namely mathematics achievement, which was obtained by averaging ten plausible values of mathematics scores. The null model represented the relationship between the intercept and the dependent variable of mathematics achievement. The results of fitting data with the null model were then used to calculate the intraclass correlation coefficient (ICC) and the design effect

to ensure that multilevel model works for analyzing data. The ICC value must be greater than 0 for applying the multilevel model, but in the social research, the ICC value was usually between 0.05 and 0.20 (Peugh, 2010). Additionally, the other requirement to use multilevel model was the value of the design effect was greater than 2.0 (Peugh, 2010). When all conditions had been met, data analysis using the multilevel model can be continued.

It was continued by forming model 1, model 2, and model 3. Model 1 was developed by adding a level-1 predictor into the null model while model 2 was formed by adding a level-2 predictor into model 1. Model 3 also used level-1 and level-2 predictors by random effect. The final model was selected based on the lowest values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The final model is used to determine whether the predictors used have an effect on students' mathematics achievement. To develop all models, data is coded in R studio version 3.6.0 using the name package (Pinheiro et al., 2021).

RESULTS AND DISCUSSION

Data analysis began with determining the descriptive statistics values of the variables of interest (see. Table 1). After removing the missing data, it showed that the average of mathematics achievement for Indonesian students was 402.60 (78.55), far below the average score attained by all participating countries (489). Additionally, a descriptive statistics for the variable of adaptive instruction shows that it is done by teachers only on a few lessons as well as feedback. However, students agreed that teachers have provided emotional support during learning. Most students also agreed that teachers feel enthusiastic when teaching. Additionally, the shortage of school resources still occurred in schools but in tiny numbers.

Table 1. Descriptive statistics for variables of interest

Variables	Min	Max	Mean (SD)
Mathematics achievement	129.60	677.80	402.60 (78.55)
Adaptive instruction	3.00	12.00	7.76 (2.28)
Teacher emotional support	3.00	12.00	9.11 (1.80)
Teacher feedback	3.00	12.00	7.71 (2.35)
Teacher enthusiasm	4.00	16.00	12.39 (2.12)
Shortage of school resources	8.00	32.00	17.43 (5.59)

Table 2. Summary of multilevel modeling results

Parameter	Null model Est. (SE)	Model 1 Est. (SE)	Model 2 Est. (SE)	Model 3 Est. (SE)
Regression coefficients (fixed effects)				
Intercept	391.88 (3.31)***	389.52 (4.84)***	469.19 (10.46)***	469.19 (10.46)***
Adaptive instruction	-	0.29 (0.28)•	0.29 (0.28) •	0.29 (0.28) •
Teacher emotional support	-	0.92 (0.33)**	0.93 (0.33)**	0.93 (0.33)**
Teacher feedback	-	-2.26 (0.27)***	-2.26 (0.27)***	-2.26 (0.27)***
Teacher enthusiasm	-	0.81 (0.29)**	0.82 (0.29)**	0.82 (0.29)**
Shortage of school resources	-	-	-4.38 (0.52)***	-4.38 (0.52)***
Variance component (random effects)				
Residual	2,630.87 (51.29)	2,610.11 (51.09)	2.609,93 (51.08)	2,602.67 (51.01)
Intercept	3,514.53 (59.28)	3,460.36 (58.82)	2,832.93 (53.22)	4,237.96 (65.1)
Slope	-	-	-	2.71
Correlation	-	-	-	-0.59
Information criterion				
AIC	105,322.5	105,250.1	105,186.5	105,190.5
BIC	105,344.1	105,300.4	105,243.9	105,262.3

Multilevel model began with a null model which only used mathematics achievement data. Using the null model, the ICC value (0.57) was calculated by dividing 3514.53 by (3514.53 + 2630.87). It demonstrated that the average of mathematics achievement score in Indonesian schools varied. The design effect value was 17.12 which was calculated by adding 1 to $\left(\frac{9,721}{332} - 1\right) \times 0.57$. As the ICC value was greater than 0 and the design effect was greater than 2.00, there was a suggestion to analyze the Indonesia PISA data using a multilevel model.

The next step was building model 1 which included a level-1 predictor. When compared to the null model, model 1 can explain approximately 1.54% of the variation at the school level and 0.79% of the variation at the student level. The results showed that adaptive instruction ($\hat{\beta} = 0.29, p < 0.10$), teacher emotional support ($\hat{\beta} = 0.92, p < 0.01$), and teacher enthusiasm ($\hat{\beta} = 0.81, p < 0.01$) were positively associated with mathematics achievement. However, teacher feedback significantly had a negative association with mathematics achievement ($\hat{\beta} = -2.26, p < 0.001$).

Model 2 was developed from model 1 with an additional level-2 predictor. When compared to the null model, model 2 explained approximately 19.25% of the variation at the school level and 0.79%

of the variation at the student level. The results show that adaptive instruction ($\hat{\beta} = 0.29, p < 0.10$), teacher emotional support ($\hat{\beta} = 0.93, p < 0.01$), and teacher enthusiasm ($\hat{\beta} = 0.82, p < 0.01$) significantly had a positive association with mathematics achievement. However, teacher feedback ($\hat{\beta} = -2.26, p < 0.001$) and shortage of school resources ($\hat{\beta} = -4.38, p < 0.001$) significantly had a negative association with mathematics achievement.

Model 3 was built by combining level-1 and level-2 predictors in the random component. When compared to the null model, model 3 explained approximately 20.58% of the variation at the school level and 1.04% of the variation at the student level. The results show that adaptive instruction ($\hat{\beta} = 0.29, p < 0.10$), teacher emotional support ($\hat{\beta} = 0.93, p < 0.01$), and teacher enthusiasm ($\hat{\beta} = 0.82, p < 0.01$) significantly had a positive association with mathematics achievement. Finally, teacher feedback ($\hat{\beta} = -2.26, p < 0.001$) and the shortage of school resources ($\hat{\beta} = -4.38, p < 0.001$) significantly had a negative association with mathematics achievement.

Model 2 had values of 105,186.5 for AIC and 105,243.9 for BIC, making it the best model based on the lowest AIC and BIC values. The shortage of school resources became the strongest predictor that affected students' mathematics achievement. The variation across schools was due to the impact of a shortage of school resources on mathematics achievement ($\widehat{\tau_{11}}$) was 2.71. The final estimated model is presented below.

$$\widehat{Math}_{ij} = 469.19 + 0.29AI_{ij} + 0.93TES_{ij} - 2.26TF_{ij} + 0.82TE_{ij} - 4.38SSR_j + \hat{U}_{0j} \quad (1)$$

The findings of the current study revealed that all student and school level predictors were important for explaining students' mathematics achievement. The teacher emotional support was statistically significant and had a positive impact on students' mathematics achievement. This result is consistent with previous research conducted by Liu et al. (2018) and Yu & Singh (2018). This is not surprising because when teachers provide strong emotional support (warm and kind, positive and respectful communication, attentive to students' needs and interests, and appropriate amounts of autonomy) then students feel relaxed and comfortable. Previous research has shown that higher levels of emotional support from teachers provide a secure atmosphere (Kunter et al., 2011). In this condition, students may work hard without fear of failure or getting unfavourable comments from teachers (Kikas & Mägi, 2017).

Based on the results, several suggestions can be offered to give emotional support. First, teachers should pay more attention to students' needs and learn how to provide the best emotional support (Jensen et al., 2019). Second, the teacher should make learning fun, respect students, and encourage (Yu & Singh, 2018). Third, the teacher must provide positive and supportive communication, consistent and responsive interaction as well as an emotionally secure environment. Fourth, the teacher can make eye contact, and provide guidance and support while speaking quietly (Merritt et al., 2012). Lastly, the teacher must also evaluate the emotional support provided to students.

In light of the research findings, adaptive instruction had a positive influence on students' mathematics achievement. This is in line with an analysis made by Brühwiler & Blatchford (2011) and Corno (2008). Adaptive learning only happens when teachers pay attention to students' needs so they feel cared for. Adaptive teachers will keep trying to attract students' attention to keep them interested in learning (Gallagher et al., 2022). Obviously, such intervention will increase students' engagement in learning. Therefore, students will not feel overwhelmed when learning mathematics, leading to higher mathematics achievement. For adaptive teaching to occur, several recommendations were given, including that teachers must evaluate student learning to determine the requirement for adaptive instruction. In addition, the teacher can also experiment with the learning methods applied in the classroom so that the teacher is accustomed to making changes because of the diversity of student's characteristics (Deed et al., 2020). Lastly, teachers must make additional changes to their objectives and methods for students who are not developing well and select content more frequently retaught.

This present study also showed that feedback given by the teacher had a statistically significant detrimental influence on students' mathematics achievement. This result is surprising because it contradicts the results of the previous study conducted by Pinger et al. (2018), and Hopfenbeck (2020). On the other hand, several previous researches revealed that teacher feedback was predicted to reduce students' achievement (Deed et al., 2020). The detrimental effects of feedback are caused by a variety of factors, such as students' motivation, perception and response (Hopfenbeck, 2020; Shute, 2008; van Der Kleij & Adie, 2020; Konnova et al., 2019). Additionally, students may not be aware that the feedback they are receiving from teachers is truly "feedback" (van Der Kleij & Adie, 2020). Moreover, students do not understand the meaning of feedback and cannot change the way they study based on the feedback given (Zheng & Yu, 2018). On the other hand, students do not pay attention to the feedback and consider it is unimportant (Carless, 2020). Therefore, even though the teacher has provided feedback, the students have not responded, and as a result, the students' achievement has not increased (Ajjawi & Boud, 2017; Winstone et al., 2017).

Another assumption that causes ineffective feedback is the type of feedback (Shintani & Ellis, 2013). In general, the teachers give feedback in the form of grades (Ghazali et al., 2020) and one or two verbal comments that are not effective (Guskey, 2019). To gain the effectiveness of feedback, teachers can implement a dialogic feedback that has been proven to improve students' mathematics achievement (Kerr, 2017; Van der Kleij et al., 2017). Additionally, Voerman et al. (2012) noted that teachers should convey detailed feedback to avoid misinterpretation. Last but not least, the teachers have to follow up students' activities to ensure that they have received, understood and responded to feedback (van der Kleij et al., 2017).

Researchers also found that teacher enthusiasm had a statistically significant influence on students' mathematics achievement. This finding is consistent with a study conducted by Mahler, Großschedl, & Harms (2018) which found that teacher enthusiasm had a beneficial influence on students' learning outcome. Moreover, there are theoretical assumptions about why teacher enthusiasm

improves learning outcomes (Jungert et al., 2020; Mahler et al., 2018). First, teacher enthusiasm may enhance students' attention since components of enthusiasm are said to attract students' attention more successfully than other external influences, such as disruptions. Second, students may imitate their teacher enthusiasm; in other words, an enthusiastic teacher may serve as a role model for students. Because of these reasons, it is not surprising that teacher enthusiasm positively impacts students' mathematics achievement. To be an enthusiastic teacher, Mahler et al. (2018), and Lazarides et al. (2019) suggested teachers should create a lively learning atmosphere, demonstrate high spirits, actively move across the class, and develop interactions through speech or eye contact.

The results also showed that a shortage of school resources had a significant negative effect on students' mathematics achievement. This finding is consistent with earlier studies that revealed enough resources in schools had a beneficial impact on students' learning outcome (Hofflinger & von Hippel, 2020; Kul et al., 2018; Wu, 2020). This finding implies that teachers and students would find it simpler to carry out the teaching and learning processes in schools with a fully functional infrastructure. So many of the best learning environments are found in schools including a wide range of resources.

In Indonesia, the shortage of school resources, especially human resources is a problem in this situation. Therefore, several suggestions can be given to the government. First, the government should continue to run the teacher certification program and should recruit more qualified teachers since the program has a potential to increase teaching quality and affect teacher performance (Harjanto et al., 2018; Kusumawardhani, 2017; Tjabolo & Herwin, 2020). Second, the government must develop proper infrastructure to support the learning process. Finally, the government must equally divide learning resources such as textbooks and technology access. If a traditional textbook distribution is judged impossible due to Indonesia's geographical characteristics, the government should supply digital textbooks (Lambert, 2019; Setiyani et al., 2020).

Overall, this research has offered a multilevel analysis in examining the effect of teacher competence and shortage of school resources on mathematics achievement using PISA 2018 data for Indonesia. This research contributes to the development of evidence-based policymaking. In terms of applicability, the findings point the way for future research by providing empirical evidence on how teacher competence and shortage of school resources influence students' mathematics achievement. This study is designed to not only serve as a reference for academics by giving information and empirical evidence but also to aid in gaining a better understanding of the effects of regulation on educational success.

According to the findings of this study, the government, particularly those in charge of education, should develop policies that encourage teachers to improve their competencies by paying more attention to the learning process in the classroom, providing emotional support, providing effective feedback, being an adaptable teacher, and providing adequate resources. Due to students' low mathematics achievement, these variables become a concern for the government to support students' mathematics achievement. Further study may be conducted to find out the most effective intervention to increase

students' mathematics achievement, particularly feedback provided by the teacher. Nevertheless, more study is required to explore other variables so it can serve as a recommendation for the government in policy-making.

CONCLUSION

Using PISA 2018 data, multilevel analysis was used to determine the factors that contributed to Indonesian students' low mathematics achievement. It was discovered that teacher feedback and shortage of school resources were statistically significant but had a negative impact on mathematics achievement, whereas teacher emotional support, adaptive teaching, and teacher enthusiasm were statistically significant but has a positive impact on students' mathematics achievement. These results indicate that the more frequent feedback provided might decrease students' mathematics achievement, same as the shortage of school resources. If the problem is unfinished, students' mathematics achievement will be lower. On the other hand, if the teachers provide frequent emotional support, are always adaptable to the learning condition and are enthusiastic, students' mathematics achievement will increase. As a result, the findings of this study can be used as a recommendation to make policies for the government to raise mathematics achievement. In addition, other countries with similar features to Indonesia might use the data to enhance mathematics achievement by implementing the suggestion provided.

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