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How Motivation mediated Science Achievement of Indonesian Students: a Path Analysis on PISA 2018 data

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Abstract: The low science achievement of Indonesian students in PISA 2018 is still a challenge for Indonesian education stakeholders. For a long time, socio-economic conditions, low interest in reading, and low motivation have often been the causes of these achievements. This study aims to examine the effects of socio-economic status, reading habits, and gender on Indonesian students' science achievements in PISA 2018. To represent the motivation variable, teacher support, parental support, and self-efficacy are placed as mediating variables toward science achievements. Using the path analysis mediation model implemented in R statistical software, we find that economic-social and cultural status, reading habits, and gender have a direct impact on students' science achievement. In addition, socio-economic and cultural status indirectly affects students' science achievement, mediated by teacher support, parental support, and self-efficacy. Reading habits indirectly affect students' science achievement, mediated by teacher support, parental support, and self-efficacy. Last, gender indirectly affects students' science achievement, mediated by parental support and self-efficacy, but does not affect students' scientific literacy scores when mediated by teacher support. Overall, gender has an indirect effect on students' science achievement.

Keywords: Mediation; Path analysis; PISA; Science literacy.

Introduction

Education is an essential need for people. It is a process that allows each person to develop themselves (Alpian et al., 2019). Along with the development of technology, students around the world need to have the ability to achieve science (Situmorang, 2016). *Science literacy* can be defined as a person's ability to apply their knowledge to identify questions, construct new knowledge, provide scientific explanations, draw conclusions based on scientific evidence, and the ability to develop a reflective mindset so that they are able to participate in addressing related issues and ideas in science (OECD, 2019a). Achievement in science literacy is essential so that students not only understand science as an "abstract" concept but are also able to apply them in everyday life.

An effort to evaluate students' achievements in science literacy in various countries is through the Program for International Student Assessment (PISA). The program is organized by the Organization for Economic Co-operation and Development (OECD). As an international survey, PISA carried out once every three years, with the first round in 2000 and subsequent rounds in 2003, 2006, 2009, 2012, 2015, and 2018. PISA's aim is to evaluate education systems around the world by testing the abilities and knowledge of students aged 15 (PISA Governing Board Indonesia, 2019). Apart from science achievements, reading literacy, and mathematics literacy are also examined and presented (OECD, 2019a). The terms of reference of all three PISA areas emphasize students' ability to apply knowledge and skills in real situations.

The 2018 PISA results show a decline in the science achievement scores of Indonesian students. The science

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achievement score of Indonesian students in 2015 was 403, while in 2018, it had an average score of 396, far below the OECD average of 489, and was ranked 71st out of 79 countries (OECD, 2019b). This result indicates that the science achievement scores of Indonesian students are still in the low category.

It is known that PISA dataset provides various information regarding students' achievement. However, most of studies on PISA dataset is focused to mathematics achievement, such as Bernardo (2021), and Kismiantini et al. (2021). Wang et al. (2023) wriote a systematic review on factors predicting mathematics achievement in PISA. Related to science achievement, Mariana (2017) identified socio-economic variables that predict student science achievement in Indonesia using PISA 2015 data with a sample of 6,513 students. Lam & Lau's (2014) study PISA 2006 data in Hong Kong with a sample of 4,645 to examine various factors that affect students' science achievements. Using hierarchical linear modeling, they find that students' gender, self-efficacy, and enjoyment of science plays important role in science achievements. Chi et al. (2018) analyze PISA data on China, and found that the association between inquiry-based science activities and science achievements is moderated by disciplinary climate. Such studies provide important information that can be used to help students' increase their achievements.

Regarding PISA 2018 in Indonesia, it was reported that the science achievements of female students were better than male students in all areas of PISA. Following Hoque (2015), Indonesia has shown significant progress in promoting gender equality by narrowing the gender gap in terms of literacy skills. Apart from the PISA survey, the low science achievement scores of students in Indonesia have been a concern in many separate studies. Socio-economic status is known to influence scientific achievement (Khairiah & Eliza, 2021). In addition, reading habits (Ayu et al., 2018; Palpani, 2012) and learning motivation (Susiati et al., 2018; Wahyuni et al., 2018) also contribute to scientific achievements. However, these studies has limitations since the data only covers one or a few schools. Consequently, a study using large dataset such as PISA data should be carried out to understand the contribution of these variables to students' science achievement.

On analyzing PISA datasets, one should be aware to the presence of mediation variable. For example, Hafizoglu & Yerdelen (2019) found that students' learning motivation towards science mediating the relationship between perceptions of the science learning environment and science achievement. Mediation analysis also used by Zeng et al. (2020), which focuses on the problem of the relationship between teacher bad behavior and students' science achievements. They analyzed 9,841 students from China's PISA 2015 data using multilevel mediation analysis. Following MacKinnon (2008), mediation model can be used to determine the relationship between variables as well as to determine the direct influence, indirect influence, and total influence on the model due to the influence of using mediating variables.

Research with several independent variables, mediating variable, and dependent variable can be carried out using the path analysis mediation model (MacKinnon, 2008). Parameter estimation in this model can be obtained through estimating parameters in the structural equation model (Schumacker & Lomax, 2016). In general, the structural equation model uses maximum likelihood estimation (MLE) to obtain the parameters (Gana & Broc, 2019). This MLE estimator has the properties of being unbiased, consistent, and efficient. However, MLE can be used only when the normality assumption is fulfilled. If the normality assumption is not met, parameter estimation with maximum likelihood and standard error for the parameter estimate results in a biased estimator. This situation can be overcome by usage of the bootstrap method to obtain standard error for parameter estimators (Wang & Wang, 2020). Therefore, path analysis mediation model is a suitable method to check the factors affecting students' science achievement in PISA datasets.

This study was conducted to investigate the relationship between economic-social and cultural status (ESCS), reading habits, and gender on students' science achievement scores in Indonesia through the mediation of learning motivation based on PISA 2018 data.

Method

This study used a quantitative approach, since PISA 2018 survey yielded many quantitative data that can be analyzed through statistics.

Data Source

This research used secondary data from PISA 2018 results which is available on the OECD website (http://oecd.org/PISA). PISA data contains individual responses from students, teachers, school principals and parents. The population in this study were all Indonesian students aged 15-16 years. For Indonesia, the 2018 PISA data consists of 12,098 students from 397 schools in Indonesia. However, this study only used a sample of Indonesian students who provided complete responses to each variable required in the research, namely 11,463 students from 397 schools.

The variable used in this study is the science achievement score as the dependent variable, which

calculated as the average (mean) value of ten available Plausible Values on science. In addition, the predictor in this study consists of economic and socio-cultural status (ESCS), reading habits, and gender, while the mediating variable was learning motivation. Definition and measurement of each independent and mediating variable is presented in Table 1.

Table 1. Variables used on this study.

Role	Variable name	Explanation	Code
Dependent	Science achievement	Arithmetic mean of the ten plausible values in science (Aparicio et al., 2021; Lazarević & Orlić, 2018; You et al., 2021)	PV1SCIE-PV10SCIE
Independent	Economic, Social, and Cultural Status (ESCS)	A standardized index representing students' background that consists of parents' higher education (HISEI), parents' occupation (PARED), and house possession (HOMEPOS) (OECD, 2019c)	ESCS
Independent	Gender	A (re-coded) dummy for students' gender: 0 = male; 1 = female	ST004D01T
Independent	Reading habits	An index made from students' agreement on several statements about reading, higher values on this scale mean that the student enjoyed reading (OECD, 2019c)	JOYREAD
Mediation	Teacher support	An index represents how students perceived their teacher to support them on learning.	TEACHSUP
Mediation	Parents support	An index represents how students perceived emotional support from their parents.	EMOSUP
Mediation	Self-efficacy	An index made from students' agreement on statements related with self-efficacy.	RESILIENCE

Data Analysis

The data analysis technique in this research uses path analysis to determine the direct and indirect influence of socioeconomic and cultural status variables, reading habits, and gender on students' science achievement scores in Indonesia, with learning motivation as a mediating variable. The data analysis process in this research uses the help of the R Studio program (R Core Team, 2022). This research uses the 'lavaan' package to divide the model into a total influence model and a mediation influence model (Rosseel, 2012). The mediation influence model in this research is divided into direct influence and indirect influence models. This research uses the maximum likelihood method to estimate parameters and bootstrap to estimate standard errors for parameter estimates. The results of the estimated standard error are used to determine the confidence interval.

Following Hayes (2022), the data analysis steps in this research are as follows:

1. Calculate descriptive statistics for each variable, which include minimum values, maximum values, (arithmetic) mean, and standard deviations.
2. Design an initial model, i.e. a mediation influence model and a total influence model using a path diagram.
3. Carry out initial identification of the mediation influence model.
4. Test the assumptions of classical regression, i.e., normality (using one sample Kolmogorov-Smirnov test), homogeneity, linearity, and multicollinearity.
5. Estimate the parameters of the mediation influence model using the *Maximum Likelihood* (ML) method. The standard error of the parameter estimator also obtained using the Bootstrap method. The results of the standard error estimation are used to build confidence intervals for the estimated parameter.
6. Test the significance of parameters of the mediation influence model using confidence intervals.
7. Determine the magnitude of the direct effect (c'), mediation or indirect effect (ab), and total effect (c).
8. Evaluate the mediation model formed using the coefficient of determination (R^2), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) (Wang & Wang, 2020).

Result and Discussion

In this section, we describe the data and then present the results of the mediation path analysis.

Descriptive Statistics

Descriptive statistics are used to understand the characteristics of each variable used in this study. The results of descriptive statistical analysis can be seen in Table 2. It appeared that in average, ESCS and self-efficacy of Indonesian students is lower than average of all PISA participants.

Table 2. Descriptive statistics of the data.

Variable	Minimum	Maximum	Mean	SD
ESCS	−5,783	2,968	−1,366	1,112
Reading	−2,711	2,613	0,495	0,612

Variable	Minimum	Maximum	Mean	SD
Teacher support	−2,710	1,341	0,368	0,851
Parent support	−2,446	1,034	0,041	0,997
Self-efficacy	−3,167	2,369	−0,012	0,843
Science achievement	189,5	685,4	416,8	68,791

Formulation of Mediation Model

We developed the mediation model presented as a path diagram in Figure 1.

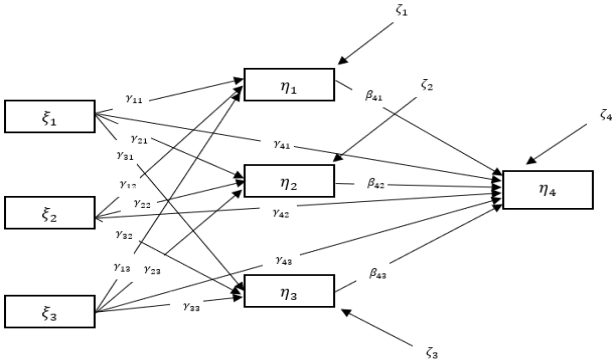

Figure 1. Path Diagram of Mediation Model in Greek notation

Following Figure 1, the mediation model can be stated in four equations as follows.

$$\eta_1 = \gamma_{11}\xi_1 + \gamma_{12}\xi_2 + \gamma_{13}\xi_3 + \zeta_1 \quad (1)$$
$$\eta_2 = \gamma_{21}\xi_1 + \gamma_{22}\xi_2 + \gamma_{23}\xi_3 + \zeta_2 \quad (2)$$
$$\eta_3 = \gamma_{31}\xi_1 + \gamma_{32}\xi_2 + \gamma_{33}\xi_3 + \zeta_3 \quad (3)$$
$$\eta_4 = \beta_{41}\eta_1 + \beta_{42}\eta_2 + \beta_{43}\eta_3 + \gamma_{41}\xi_1 + \gamma_{42}\xi_2 + \gamma_{43}\xi_3 + \zeta_4 \quad (4)$$

or, in matrix notation,

$$\begin{bmatrix}\eta_1\\ \eta_2\\ \eta_3\\ \eta_4\end{bmatrix} = \begin{bmatrix}0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\\ \beta_{41} & \beta_{42} & \beta_{43} & 0\end{bmatrix}\begin{bmatrix}\eta_1\\ \eta_2\\ \eta_3\\ \eta_4\end{bmatrix} + \begin{bmatrix}\gamma_{11} & \gamma_{12} & \gamma_{13}\\ \gamma_{21} & \gamma_{22} & \gamma_{23}\\ \gamma_{31} & \gamma_{32} & \gamma_{33}\\ \gamma_{41} & \gamma_{42} & \gamma_{43}\end{bmatrix}\begin{bmatrix}\xi_1\\ \xi_2\\ \xi_3\end{bmatrix} + \begin{bmatrix}\zeta_1\\ \zeta_2\\ \zeta_3\\ \zeta_4\end{bmatrix} \quad (5)$$

where η_1, η_2, and η_3 represent the mediation variables (teacher support, parents support, and self-efficacy) and η_4 represent the dependent variable (i.e. students science achievement). In addition, ξ_1, ξ_2, and ξ_3 denote the independent variables, i.e. ESCS, reading habits, and gender, respectively. Last, $\zeta_1, \zeta_2, \zeta_3$, and ζ_4 denote the error of the model.

Model Identification and Estimation

Model identification is carried out by comparing the number of parameters estimated in the model with the variance-covariance of the measured variables. The number of parameters to be estimated is determined by knowing the elements of the variance-covariance matrix and the model coefficient matrix. The number of estimated parameters and the number of unique elements is stated in Table 3.

Table 3. Element of parameters in the model

Matrix	Elements	Number of parameters
$\boldsymbol{\psi}$	$\psi_{11}, \psi_{21}, \psi_{22}, \psi_{31}, \psi_{32}, \psi_{33}, \psi_{44}$	7
$\boldsymbol{\Phi}$	$\Phi_{11}, \Phi_{12}, \Phi_{13}, \Phi_{22}, \Phi_{23}, \Phi_{33}$	6
$\boldsymbol{\Gamma}$	$\gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{21}, \gamma_{22}, \gamma_{23}, \gamma_{31}, \gamma_{32}, \gamma_{33}, \gamma_{41}, \gamma_{42}, \gamma_{43}$	12
$\boldsymbol{\beta}$	$\beta_{41}, \beta_{42}, \beta_{43}$	3
Total		28

Based on Table 2, the model is identified as a just identified model because the number of parameters estimated and the number of unique elements are the same, i.e. 28. Therefore, the model does not have zero degrees of freedom and can be estimated.

Prior to the estimation, we need to check several classical assumptions. We found that the linearity, homoscedasticity, and multicollinearity assumption are met for all four models. However, the normality assumption is met for the fourth model, but not for the first, second, and third model. Consequently, inference of the model could not be carried out parametrically.

In this study, parameter estimation was carried out using the Maximum Likelihood method, followed by bootstrap to estimate its standard error. The number of bootstrap samples in this study is 1,000. All procedure carried out using lavaan library in R yield the results as presented in Table 4. Note that there are four models here, which represented by equation (1), (2), (3), and (4) above.

For the first model, the confidence interval for ESCS ($\widehat{\gamma_{11}} = -0.043, -0.057 < \gamma_{11} < -0.029$), reading habit ($\widehat{\gamma_{12}} = 0.163,\ 0.137 < \gamma_{12} < 0.188$), and gender ($\widehat{\gamma_{13}} = 0.034,\ 0.001 < \gamma_{13} < 0.064$) did not across zero, meaning that these three variables significantly affect teacher supports. As the coefficient for ESCS is negative, we can say that higher ESCS related to a decrease in teacher support. In contrast, reading habit has a significant positive relation with teacher support. This result also demonstrate that male students obtain better teacher support than female ones.

For the second model, we find that the confidence interval of ESCS ($\widehat{\gamma_{21}} = 0.066,\ 0.051 < \gamma_{21} < 0.083$), reading habit ($\widehat{\gamma_{22}} = 0.279,\ 0.249 < \gamma_{22} < 0.311$), and gender ($\widehat{\gamma_{23}} = -0.095, -0.131 < \gamma_{33} < -0.061$) did not

contain zero, which means that these three variables significantly affect parents support. Increase of ESCS and reading habit related to the increase of parents' support for 0.066 and 0.279, respectively.

The third model used to predict students' self-efficacy. From Table 4, we obtain the estimated confidence interval for ESCS ($\widehat{\gamma_{31}} = 0.022,\ 0.009 < \gamma_{31} < 0.035$), reading habit ($\widehat{\gamma_{32}} = 0.264,\ 0.234 < \gamma_{32} < 0.294$), and gender ($\widehat{\gamma_{33}} = 0{,}065, 0{,}034 < \gamma_{33} < 0{,}094$). All the three confidence intervals did not contain zero, meaning that these three variables have significant effect to students' self-efficacy. Students with higher ESCS index and/or higher reading habit tend to have higher self-efficacy.

Last, Table 4 also presents the estimation result for Model 4, in which students' science achievement become the dependent variable. In this model, all mediation variables, i.e. teacher support, parents support, and self-efficacy, affect students' science achievement, since the confidence interval did not contain zero. Moreover, all independent variables, i.e. gender, ESCS, and reading habit also significant. By examining the sign of estimated coefficient, students with higher ESCS, higher reading habit, and higher parents' support tend to have higher science achievement. In contrast, increase in teacher support and increase in self-efficacy related to lower science achievement.

Direct, Indirect, and Total Effect

Based on these estimated coefficients, we calculate and obtain the direct effect, indirect (mediated) effect, and total effect as presented in Table 5, Table 6, and Table 7, respectively.

Following Table 5, direct effect of ESCS to science achievement (c_1') equal to 23.770, with confidence interval $22.742 \leq \gamma_{41} \leq 24.811$. Similarly, we obtain the direct effect of reading habit to science achievement (c_2') as 9.890 with confidence interval $7.834 \leq \gamma_{42} \leq 11.919$. These result show that both ESCS and reading habit have significant positive direct effect to students' science achievement. Regarding students' gender, we obtain the coefficient (c_3') equal to -6.817, with confidence interval $-9.110 \leq \gamma_{43} \leq -4.403$. This result show that female students directly exhibit lower science achievement compared to male students.

Table 4. Results of parameter estimation

Regression	Coefficient estimation	Standard error	95% Confidence interval lower	upper
Model 1				
Intercept	0.178	0.028	0.126	0.236
ESCS → Teacher Support (γ_{11})	−0.043	0.007	−0.057	−0.029
Reading Habit → Teacher Support (γ_{12})	0.163	0.013	0.137	0.188
Gender → Teacher Support (γ_{13})	0.034	0.016	0.001	0.064
Model 2				
Intercept	0.134	0.032	0.072	0.198
ESCS → Parents Support (γ_{21})	0.066	0.008	0.051	0.083
Reading Habit → Parents Support (γ_{22})	0.279	0.016	0.249	0.311
Gender → Parents Support (γ_{23})	−0.095	0.018	−0.131	−0.061
Model 3				
Intercept	−0.209	0.028	−0.263	−0.152
ESCS → Self-efficacy (γ_{31})	0.022	0.007	0.009	0.035
Reading Habit → Self-efficacy (γ_{32})	0.264	0.015	0.234	0.294
Gender → Self-efficacy(γ_{33})	0.065	0.015	0.034	0.094
Model 4				
Intercept	454.786	2.080	450.670	459.104
Teacher Support → Science achievement (β_{41})	−2.050	0.720	−3.480	−0.633
Parents Support → Science achievement (β_{42})	8.959	0.604	7.822	10.207
Self-efficacy → Science achievement (β_{43})	−6.065	0.738	−7.552	−4.701
ESCS → Science achievement (γ_{41})	23.770	0.524	22.742	24.881
Reading Habit → Science achievement (γ_{42})	9.890	1.021	7.834	11.919
Gender → Science achievement (γ_{43})	−6.817	1.146	−9.110	−4.403

Table 5. Direct effect of independent variables

Direct effect	Estimation	SE	95% confidence Interval lower	upper
ESCS → Science achievement	23.770	0.524	22.742	24.811
Reading habit → Science achievement	9.890	1.021	7.834	11.919
Gender → Science achievement	−6.817	1.146	−9.110	−4.403

Table 6. Indirect (mediated) effect of independent variables

Indirect effect	Estimation	SE	Confidence Interval	
			2.5%	97.5%
ESCS → Teacher Support → Science achievement	0.089	0.034	0.026	0.163
ESCS → Parents support → Science achievement	0.591	0.083	0.439	0.767
ESCS → Self-efficacy → Science achievement	−0.133	0.046	−0.236	−0.049
Total indirect effects of ESCS	0.547	0.093	0.369	0.736
Reading habit → Teacher Support → Science achievement	−0.334	0.121	−0.577	−0.107
Reading habit → Parents support → Science achievement	2.497	0.216	2.122	2.957
Reading habit → Self-efficacy → Science achievement	−1.602	0.213	−2.032	−1.201
Total indirect effects of reading habit	0.561	0.297	0.010	1.168
Gender → Teacher Support → Science achievement	−0.069	0.042	−0.162	0.000
Gender → Parents support → Science achievement	−0.849	0.176	−1.199	−0.519
Gender → Self-efficacy → Science achievement	−0.393	0.106	−0.613	−0.191
Total indirect effects of gender	−1.311	0.193	−1.716	−0.952

Table 7. Total Effects

Effects	Estimation	Confidence interval	
		2.5%	97.5%
ESCS → Science achievement	24.317	22.642	25.056
Reading habit → Science achievement	10.451	7.611	11.770
Gender → Science achievement	−8.128	−9.696	−4.204

Table 6 shows that all the 95% confidence intervals for indirect effect of ESCS to the science achievement through all mediation variables did not contain zero. In other words, the relationship between ESCS and science achievement is mediated by teacher support, parents support, and self-efficacy. Similarly, from the confidence intervals we know that the relationship between reading habits and science achievement are also significantly mediated by teacher support, parents support, and self-efficacy. In contrast, the relationship between gender and science achievement only significantly mediated by parents' support and self-efficacy. The mediation effect of teacher support to the relationship between gender and science achievement is not significant since the confidence intervals contains zero.

Table 7 presents the total effect of the three independent variables to students' science achievement. The estimated effects size of ESCS and reading habit to science achievement is 24.317 and 10.451, respectively. Both the confidence interval of these two estimations did not contain zero, which means that ESCS and reading habit significantly have positive effects to students' ESCS. On the other hand, the estimated effect size of gender is −8,128, implying that female students has significantly lower science achievement when compared to male students.

Model Evaluation

In this study, model evaluation was carried out through examine the coefficient of determination (R^2), CFI, TLI, RMSEA, and SRMR. From the software, we obtain the R^2 for this mediated model equal to 0.257, which implies that about 25.7% variations of students science achievement can be explained by this mediation model, while the other 74.3% explained by variables outside this model. Following Cohen et al. (2003), this coefficient of determination belongs to medium effect, since it lies between 0.13 and 0.26. The CFI and TLI of this study is $1 > 0.9$, the RMSEA is $0 < 0.06$, and the SRMR is $0 < 0.08$, means that this path mediation model is in good fit.

Discussion

This analysis shows that ESCS or economic, social, and cultural status have a significant effect on teacher support, parental support, and self-efficacy. This result is in line with Muharochma & Abduh (2022), which states that teachers as facilitators in schools have an important role in facilitating student learning, especially for students who have low socio-economic status backgrounds, to ensure students can really study in class and feel confident. Israel et al. (2021) also stated that good socio-economic status and learning guidance from parents make students' learning motivation better. Hsieh & Huang (2014) also stated that socio-economic status and proactive personality have a positive influence on self-efficacy in career decision making. The presence of indirect effect of ESCS on students' science achievement also in-line with Khairiah & Eliza (2021), which states that the socio-economic and cultural background of parents is very important in supporting facilities for children's learning and scientific development.

Reading habit can be defined as a behavior that makes reading a hobby and is related to everyone's

reading taste (Sangkaeo, 1999). Making reading as something enjoyable will increase student learning outcomes (Hughes-Hassell & Rodge, 2007). In this study, reading habit have a significant effect on teacher support, parent support, and self-efficacy. This result is in line with Yanti et al. (2020), which states that reading habits directly influence learning motivation. The direct and indirect influence of reading habit to students' science achievement scores is in line with Yanti et al. (2020), which states that reading habits have the greatest influence on the ability to achieve science both directly and indirectly.

This study shows that gender has a significant effect on parental support and self-efficacy, but no effect on teacher support. Research on gender with teacher support is still very limited, but there are previous studies that show the same results as this research. Vekiri (2010) showed that there were no differences between boys and girls in terms of teacher perceptions and support. Research by Malecki & Demaray (2003) and De Wit et al. (2010) also stated that gender does not affect teacher support, which means that boys and girls feel the same level of teacher support.

How the three mediation variables affect students' science achievements? In this study, we find that teacher support, parental support, and self-efficacy influence students' science achievement scores. This result is supported by Bagiarta et al. (2015), which found that learning motivation influences students' science achievement.

This study show that gender directly influences students' science achievement scores. Even though gender only has an indirect effect through the mediation of parental support and self-efficacy, gender indirectly has a total effect on students' science achievement scores. Similarly, Mukti et al. (2019), which states that there is a significant difference between the science achievement abilities of male and female students. Female students tend to have better science achievement abilities than male students.

Limitation of this study is as follows. First, it is possible that there are some possible relations between PISA variables that differ from path model used in this study. For example, Liu & Wang (2022) note that self-efficacy is related with teacher support, a situation that is not confirmed in this study since both teacher support and self-efficacy become mediating variables. Second, PISA 2018 is used due to its contemporary or novelty. However, it must be realized that the focus of PISA 2018 is in reading literacy, so that numerous science-specific variables are not examined in this PISA. We hope that the results of this study can be confirmed through the PISA 2025 data, which also focused on science literacy.

Conclusion

Based on the results of the analysis, it can be concluded that socio-economic and cultural status, reading habits, and gender influence teacher support, parental support, and self-efficacy. The mediators of teacher support, parental support, and self-efficacy influence students' science achievement scores. Apart from that, in the direct influence results, socio-economic and cultural status, reading habits, and gender influence students' science achievement scores. In addition, based on the results of indirect effects, socio-economic and cultural status, and reading habits influence students' science achievement scores, which are mediated by teacher support, parental support, and self-efficacy. However, based on the indirect effects, gender influences students' science achievement scores, which are mediated by parental support and self-efficacy. Gender does not affect science achievement scores, which are mediated by teacher support. However, based on the results, gender has a total indirect effect on students' science achievement scores.

In this study, the gender variable did not affect students' science achievement scores through teacher support as a mediating variable. Future studies should review the theories that link these variables and add or use other mediating variables or interactions.

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Author Contributions

Conceptualization, EPS, CPNC.; methodology, CPNC, EPS.; software, CPNC.; validation, EPS; formal analysis, CPNC; investigation, EPS; resources, CPNC, EPS; writing—original draft preparation, CPNC; writing—review and editing, EPS; visualization, CPNC; supervision, EPS. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Alpian, Y., Anggraeni, S. W., Wiharti, U., & Soleha, N. M. (2019). Pentingnya pendidikan bagi manusia. *Jurnal Buana Pengabdian*, *1*(1), 66–72.

Aparicio, J., Cordero, J. M., & Ortiz, L. (2021). Efficiency analysis with educational data: How to deal with plausible values from international large-scale assessments. *Mathematics*, *9*(13), 1579. https://doi.org/10.3390/math9131579

Ayu, N. A., Suryanda, A., & Dewi, R. (2018). Hubungan kebiasaan membaca dengan kemampuan literasi sains siswa SMA di Jakarta Timur. *Jurnal Ilmiah Biologi*, *7*(2), 161–171. https://doi.org/https://doi.org/10.26877/bioma.v7i2.2804

Bagiarta, I. N., Karyasa, I. W., & Suardana, I. N. (2015). Komparasi literasi sains antara siswa yang dibelajarkan dengan model pembelajaran kooperatif tipe gi (group investigation) dan model pembelajaran inkuiri terbimbing (guided inquiry) ditinjau dari motivasi berprestasi siswa smp. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *5*(2).

Bernardo, A. B. I. (2021). Socioeconomic status moderates the relationship between growth mindset and learning in mathematics and science: Evidence from PISA 2018 Philippine data. *International Journal of School & Educational Psychology*, *9*(2), 208–222. https://doi.org/https://doi.org/10.1080/21683603.2020.1832635

Chi, S., Liu, X., Wang, Z., & Han, S. W. (2018). Moderation of the effects of scientific inquiry activities on low SES students' PISA 2015 science achievement by school teacher support and disciplinary climate in science classroom across gender. *International Journal of Science Education*, *40*(11), 1284–1304.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression correlation analysis for the behavioral sciences (third edition)*. London: Lawrence Erlbaum Associates.

De Wit, D. J., Karioja, K., & Rye, B. J. (2010). Student perceptions of diminished teacher and classmate support following the transition to high school: Are they related to declining attendance? *School Effectiveness and School Improvement*, *21*(4), 451–472. https://doi.org/10.1080/09243453.2010.532010

Gana, K., & Broc, G. (2019). *Structural equation modeling with lavaan*. London: ISTE Ltd.

Hafizoglu, A., & Yerdelen, S. (2019). The role of students' motivation in the relationship between perceived learning environment and achievement in science: A mediation analysis. *Science Education International*, *30*(4), 251–260. https://doi.org/10.33828/sei.v30.i4.2

Hayes, A. F. (2022). *Introduction to mediation, moderation, and conditional process analysis: a regression-based approach* (Third Edition). New York: The Guilford Press.

Hoque, U. S. (2015). Summary of indonesia's gender analysis. *ADB Papers on Indonesia*.

Hsieh, H. H., & Huang, J. T. (2014). The effects of socioeconomic status and proactive personality on career decision self-efficacy. *The Career Development Quarterly*, *62*(1), 29–43. https://doi.org/10.1002/j.2161-0045.2014.00068.x

Hughes-Hassell, S., & Rodge, P. (2007). The leisure reading habits of urban adolescents. *Journal of Adolescent & Adult Literacy*, *51*(1), 22–33. https://doi.org/10.1598/jaal.51.1.3

Israel, V. V., Korompis, C., & Rooroh, A. R. (2021). *Pengaruh status sosial ekonomi dan bimbingan belajar orang tua terhadap motivasi belajar siswa kelas xi program study administrasi perkantoran di smk n 1 bitung*.

Khairiah, F., & Eliza, D. (2021). Kontribusi latar belakang sosial ekonomi orang tua di masa covid-19 terhadap perkembangan sains anak (survei pada anak taman kanak-kanak di Kecamatan Bukik Barisan). *Jurnal Aplikasi IPTEK Indonesia*, *5*(2), 86–92. https://doi.org/10.24036/4.25455

Kismiantini, Setiawan, E. P., Pierewan, A. C., & Montesinos-López, O. A. (2021). Growth mindset, school context, and mathematics achievement in Indonesia: A multilevel model. *Journal on Mathematics Education*, *12*(2), 279–294. https://doi.org/10.22342/jme.12.2.13690.279-294

Lam, T. Y. P., & Lau, K. C. (2014). Examining factors affecting science achievement of Hong Kong in PISA 2006 using hierarchical linear modeling. *International Journal of Science Education*, *36*(15), 2463–2480. https://doi.org/10.1080/09500693.2013.879223

Lazarević, L. B., & Orlić, A. (2018). PISA 2012 mathematics literacy in serbia: A multilevel analysis of students and schools. *Psihologija*, *51*(4), 413–432.

Liu, Y., & Wang, J. (2022). The mediating–moderating model of inquiry-based learning and science self-efficacy: evidence from PISA 2015. *International Journal of Science Education*, *44*(7), 1096–1119.

MacKinnon, D. P. (2008). Introduction to Statistical Mediation Analysis. In *Multivariate Applications Series*. New York: Lawrence Erlbaum Associates: Routledge Academic.

Malecki, C. K., & Demaray, M. K. (2003). What type of support do they need? investigating student adjustment as related to emotional, informational, appraisal, and instrumental support. *School Psychology Quarterly*, *18*(3), 231–252.

Mariana. (2017). The relationship between parents' socio-economic background and students' science literacy in Indonesia: Evidence from programme for international students assessment (PISA) 2015. *Proceedings of Social Sciences, Humanities and Economics Conference*, *108*.

Muharochma, W., & Abduh, M. (2022). Upaya guru dalam memfasilitasi siswa berlatar belakang status sosial ekonomi (SSE) rendah di sekolah dasar. *Jurnal Basicedu*, *6*(4), 6197–6202. https://doi.org/10.31004/basicedu.v6i4.3199

Mukti, W. R., Yuliskurniawati, I. D., Noviyanti, N. I., Mahanal, S., & Zubaidah, S. (2019). A survey of high school students' scientific literacy skills in different gender. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1241/1/012043

OECD. (2019a). *PISA 2018 results: What students know and can do*. Paris: OECD Publishing.

OECD. (2019b). *PISA 2018 results: What school life means for student's lives*. Paris: OECD Publishing.

OECD. (2019c). *PISA 2018 results: Where all students can succeed*. Paris: OECD Publishing. https://doi.org/10.1787/b5fd1b8f-en

Palpani, K. K. (2012). Promising reading habits an creating literate social. *International Reference Research Journal*, *3*(2).

PISA Governing Board Indonesia. (2019). Pendidikan di Indonesia belajar dari hasil PISA 2018. *Pusat Penilaian Pendidikan Balitbang Kemendikbud*.

R Core Team. (2022). *A language and environment for statistical computing*. Vienna, Austria: https://www.R-project.org/.

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2), 1–36. https://doi.org/doi:10.18637/jss.v048.i02

Sangkaeo, S. (1999). Reading habit promotion in ASEAN libraries. *International Federation of Library Associations and Institutions*, 8.

Schumacker, R. E., & Lomax, R. G. (2016). *A beginner's guide to structural equation modeling*. New York: Routledge.

Situmorang, R. P. (2016). Integrasi literasi sains peserta didik dalam pembelajaran sains. *Satya Widya*, *32*(1), 49–56.

Susiati, A., Adisyahputra, & Miarsyah, M. (2018). Correlation of comprehension reading skill and higher-order thinking skill with scientific literacy skill of senior high school biology teacher. *Biosfer: Jurnal Pendidikan Biologi (BIOSFERJPB)*, *11*(1), 1–12. https://doi.org/10.21009/biosferjpb.11-1.1

Vekiri, I. (2010). Boys' and girls' ICT beliefs: Do teachers matter? *Computers and Education*, *55*(1), 16–23. https://doi.org/10.1016/j.compedu.2009.11.013

Wahyuni, S., Miarsyah, M., & Adisyahputra. (2018). Correlation between achievement motivation and reading comprehension ability through science literacy to high school students. *Indonesian Journal of Science and Education*, *2*(2), 115–124. https://doi.org/10.31002/ijose.v2i2.613

Wang, J., & Wang, X. (2020). *Structural equation modeling applications using mplus*. Hoboken: John Wiley & Sons.

Wang, X. S., Perry, L. B., Malpique, A., & Ide, T. (2023). Factors predicting mathematics achievement in PISA: a systematic review. *Large-Scale Assessments in Education*, *11*(1), 24. https://doi.org/10.1186/s40536-023-00174-8

Yanti, R., Prihatin, T., & Khumaedi. (2020). Analisis kemampuan literasi sains ditinjau dari kebiasaan membaca, motivasi belajar dan prestasi belajar. *INKUIRI: Jurnal Pendidikan IPA*, *9*(2), 147–155. https://doi.org/10.20961/inkuiri.v9i2.27422

You, H. S., Park, S., & Delgado, C. (2021). A closer look at US schools: What characteristics are associated with scientific literacy? A multivariate multilevel analysis using PISA 2015. *Science Education*, *105*(2), 406–437.

Zeng, B., Zhang, J., & Wen, H. (2020). The relationship between teachers' misbehavior and students' scientific literacy: The mediation effect of students' scientific interest. *ACM International Conference Proceeding Series*, 66–71. https://doi.org/10.1145/3404709.3404714