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Hierarchical linear modeling for determining the effect of ICT literacy on mathematics achievement

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ABSTRACT

This study aims to identify the effect of ICT literacy on mathematics achievement in grade 8 by using the Indonesian Student Competency Assessment's (*Asesmen Kompetensi Siswa Indonesia* or AKSI) 2019 questionnaire data. A multistage probability sample of 13,079 students was analyzed using a two-level hierarchical linear model (HLM) which student achievement scores are the first level laid in schools as the second level. The results of the analysis revealed that SES, the number of smartphones and computers that students have at home, the availability of ICT at home and school, the use of ICT for education, and perspective on the benefits of ICT in daily life have a positive influence on mathematics literacy achievement, while the easiness of access to the use of digital devices in schools has negative influence at the student level. At the school level, the high mathematics literacy achievement of students is influenced by the location of the school and the number of certified teachers. School accreditation and completeness of learning facilities in schools are not factors upon better students toward their mathematics literacy achievement. However, the interaction between the easiness of access to the use of digital devices in schools and the completeness of learning facilities in schools have an influence in increasing students' mathematics literacy achievement. Based on the diversity component, it is known that the diversity of students' mathematical literacy achievement explained by the student level and school-level variables are 33.24 and 0.18, respectively.

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INTRODUCTION

The 21st century or the era of the global economy forces the education sector to prepare students as the next generation to master life and career skills, learning and innovation, and information, media, and technology (Trilling & Fadel, 2009). One of these information, media, and technology skills is ICT (Information, Communications, and Technology) literacy. This literacy is defined as the skills to use digital technology, communication devices, and internet networks to access, organize, integrate, assess, and make information useful in an educated society (Educational Testing Service, 2002; Syarifuddin, 2014). Until now, ICT literacy is better understood as computer literacy, internet literacy (Juditha, 2017), or digital skills. This literacy must also be supported by support systems such as assessment standards, instruction and curriculum, professional development, and a learning environment.

In Indonesia, the Center for Assessment and Learning under the Research and Development Agency of the Ministry of Education and Culture, has an important role as a support system that handles assessment standards. This contribution was realized in AKSI (*Asesmen Kompetensi Siswa Indonesia)* or Indonesian Student Competency Assessment. AKSI is a national education

quality achievement mapping program consisting of AKSI for schools and AKSI surveys. Instruments for the AKSI survey consist of cognitive instruments and questionnaire instruments. Cognitive instruments are in the form of questions on reading literacy, scientific literacy, and mathematical literacy. The questionnaire was distributed to school principals, teachers, and students (Center for Educational Assessment of the Ministry of Education and Culture, 2019a).

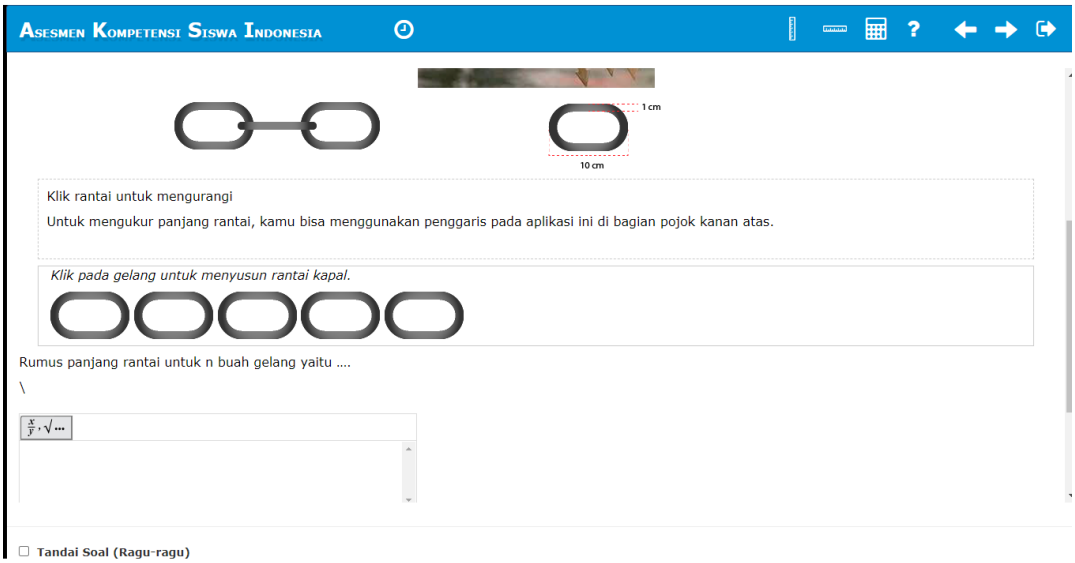

Figure 1. Example of the Published Math Problem with Stimulus Arranging the Chain (Center for Educational Assessment of the Ministry of Education and Culture, 2019b)

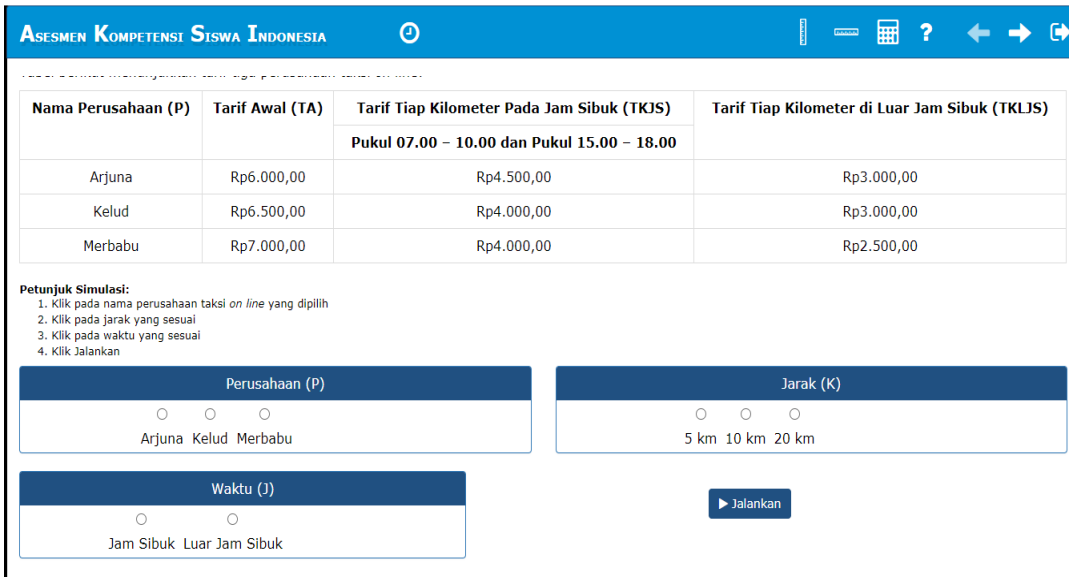

Figure 2. Example of the Published Math Problem with Stimulus Title "Online Taxi" (Center for Educational Assessment of the Ministry of Education and Culture, 2019b)

The results of the 2019 AKSI based on cognitive instruments show that nationally, reading literacy is in the low (55.85%), moderate (38.01), and good (6.14%) positions; scientific literacy is in a low position (66.11%), moderate (33.12%), and good (1.78%), and; mathematical literacy is in the low (79.44%), moderate (18.98%), and good (1.58%) positions. These data provide information from the three literacy, and mathematical literacy is at the top for the less category. Especially for mathematics, students can only solve routine simple math problems, basic computations in the form of direct equations, and basic concepts related to geometry and statistics. We can see from the published math problems, for example, questions with algebraic content-number pat-

terns, with the stimulus "students are asked to click on a bracelet to arrange a chain and use a ruler in the application in the right corner to measure the length of the chain", as presented in Figure 1. For another question with the stimulus title "Online Taxi", students are asked to click the simulation section followed by pressing the "run" button, as presented in Figure 2.

Based on these two questions, it is found that students did not just make calculations based on mathematical skills but also required proficiency in using digital media. However, cognitive elements such as being used (Fishbein & Ajzen, 1975) or not in using digital media devices also influence students writing answers. Today's digital media skills are better known as ICT literacy.

With regard to ICT literacy, based on a student questionnaire in the digital proficiency section, It is known that 50% nationally the availability of digital devices at schools and at home. Digital devices have been used in learning (50%) and support learning activities (49.86%). Students also give a positive response to using digital devices in future learning (50.27%) (Center for Educational Assessment of the Ministry of Education and Culture, 2019c).

Based on this report, it is known that digital devices as support systems are no longer an obstacle in the learning environment. It means that students' ICT literacy supports them in making it easier to find learning content from various sources themselves. Align with the results of Helaluddin (2019), technology-based learning is a solution for millennial students who prefer something new that is oriented towards the process of self-discovery (student-centered).

Apart from the use of digital media, a support system that needs to be considered is professional development. Based on the school questionnaire, the percentage of teachers who have been certified, it is known that there are 38.5% of teachers who are mostly not yet certified, 29.7% of teachers who are already certified, and 28.69% who are already certified is more than 80% of the total number of teachers in schools. This provides information that teachers in the country have not reached half of those who are certified. Supposedly, teacher certification is one of the administrative requirements for teacher professionalism (Law No. 14 of 2005 of Republic of Indonesia about Teachers and Lecturers).

Professional development as a support system is also related to school accreditation. According to BAN-S/M (*Badan Akreditasi Nasional* or National Accreditation Board for schools/*madrasahs*, school accreditation is categorized into Accreditation A, B, C, and Not Accredited). The results of the questionnaire show that 53.65% of schools are in category A, 25.64% are in category B, 17.86% are in category C, and only 1.69% of schools are not accredited. This is an increase compared to the results of the accreditation carried out by BAN-S/M in 2019 for 62,365 schools throughout Indonesia (Chaterine, 2019). They are Accreditation A (25.34%), Accreditation B (54.24%), Accreditation C (18.15%), and Not Accredited (2.27%). This provides information that accreditation is indeed an indicator of quality improvement education in order to achieve quality standards. For teachers, the results of school/*madrasah* accreditation are motivation to improve themselves in providing the best service for students (Nujumuddin, 2019).

Ideally, the variables in the school questionnaire contribute more or less to the results of mathematical literacy (as well as other literacy). Of course, a more in-depth analysis is needed, which variables are predicted to affect the results of mathematical literacy based on the 2019 AKSI ICT Literacy questionnaire. In this paper, the model used is Hierarchy Linear Modeling (HLM). The information obtained from the results of the mathematical literacy cognitive instrument was used as level 1 variables, while the ICT literacy questionnaire and the school location questionnaire, teacher certification, and school accreditation were made level 2.

METHOD

This study uses AKSI survey data in 2019 for 8th-grade junior high school students. The samples were determined using multi-stage probability sampling. The first stage selects sample districts/cities, the second stage selects sample schools, and the third stage selects sample students. The sample used in this study consisted of 13.079 students. The data were obtained from the Center for Educational Assessment of the Ministry of Education and Culture (2019a).

AKSI 2019 consists of two types of measurement, AKSI for schools and AKSI for surveys. AKSI for schools is a tool provided by the Center for Assessment and Learning, Ministry of Education and Culture of the Republic of Indonesia, in the form of a formative assessment module used to determine student abilities on essential topics in language, mathematics, and science lessons. The AKSI survey is a program for mapping educational attainment to monitor the quality of education at the national/regional level, which describes the achievement of students' abilities done through a "longitudinal" survey. The instrument used in AKSI for schools is a cognitive instrument consisting of mathematics, science, and reading test modules, while the instruments used in the AKSI survey were cognitive instruments and questionnaire. The AKSI survey questionnaire instrument consisted of questionnaires for school principals, teachers, and students (Center for Educational Assessment of the Ministry of Education and Culture, 2019a).

This study uses student questionnaires and student cognitive results of mathematics scores. Furthermore, the student questionnaire used for data analysis was a questionnaire to measure students' ICT literacy and school questionnaire. A total of eight questions were taken from the ICT literacy questionnaire and four questions from the school questionnaire that were considered relevant to support this study. Table 1 describes the variables used from the ICT literacy questionnaire, while Table 2 describes the variables used from the School Questionnaire.

Table 1. Description for ICT Literacy Questionnaire

Variable	Description
Sex	This variable explains the gender of the student
SES	This variable describes student's social economics based on parental education and income
Ownership of goods at home	This variable describes the types of items students have at home
Availability of ICT at school and home	This variable describes the IT devices in schools and at students' home
Student opinions about ICT access in schools	This variable explains students' opinions about the easiness of access and the skills of teachers towards IT in schools
ICT usage for education	This variable explains the frequency of students using IT for educational purposes
ICT usage for entertainer	This variable explains the frequency of students using IT for other than educational purposes
Perspective on the benefits of ICT in daily life	This variable describes the benefits of IT for student's daily life

Table 2. Descriptions for School Questionnaire

Variable	Description
School location	This variables describes the conditions around the student's school environment
Teacher certification	This variable describes the percentage of certified teachers in school
School accreditation	This variable describes the school accreditation
Teaching and learning using ICT devices	This variable describes teaching and learning activities using ICT devices

This study aims to examine the effect of students' ICT literacy on mathematics literacy scores in AKSI 2019 using hierarchical linear model (HLM) modeling. A two-level HLM was used to examine the effects of individual- and school-level variables on mathematics literacy scores. This analysis approach was chosen because the study data have a hierarchical structure with individual students nested within the school. In our study, models were applied in the order of Model 1 (only dependent variables used), Model 2 (Model 1 + individual context variables), Model 3 (Model 2 + school context variables), Model 4 (Model 3 + school context variables) and Final Model (Model 4 + interaction of school and individual context variables) to separately identify the impact of the information-related variables. The analysis models are as follows.

Level-1 model (Student level):

$$Y_{ij} = \beta_{oj} + \sum_{q=1}^{5} \beta_{qj}(X_q)_{ij} + e_{ij}, \quad e_{ij} \sim N\left(0, \delta^2\right)$$

Level-2 model (School level):

$$\beta_{oj} = \gamma_{00} + \sum_{s=1}^{4} \gamma_{0s}(W_S) + u_{oj}$$

$$\beta_{1j} = \gamma_{10} \ldots\ldots \beta_{qj} = \gamma_{q0}, \quad u_{oj} \sim N\left(0, \delta^2\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In Formula (1), Yij is the mathematics score of student 'i' going to junior high school 'j'. In order to estimate the value, seven individual-level variables (X) and four school-level variables (W) were applied in order. Group-mean centering was conducted for all X(s) and grand mean centering for all W(s) except for the dummy variables. Therefore, the intercept βoj of the model was the average mathematics score of the students.

FINDINGS AND DISCUSSION

Analysis on Variables Affecting the Mathematics Score Using HLM

We examined the results of the final model of HLM analysis to identify the significant variables affecting the students' mathematics literacy scores. The results are presented in Table 3. First, the students' mathematical achievement diversity explained by the student level and school-level variables are 33.24 and 0.18, respectively.

Based on the family social-economic status (SES), it appears that the score of students who had a good SES was 2.06 points higher than that of students who had not. In line with the use of ICT for education and students' perspectives on ICT use in daily life has a positive effect on mathematics literacy scores. The score increased by 4.55 points and 3.28 points for an increase in every unit of computer usage time for education and daily life, respectively. In addition, the students' smartphones and computers, the availability of digital devices at home and school have a positive effect on mathematics literacy scores. Meanwhile, the easiness of access to the use of digital devices in schools has a negative effect. This means that students' access to ICT in schools does not guarantee students' mathematics score is better. However, the scores decreased by 1.74 points for the easiness of access to the use of ICT in schools.

With regard to information variables of the school level, the mathematics score of schools located in major cities was 0.55 points higher than that of schools located in islands or isolated and rural areas. The more certified teachers in the school, the mathematics literacy score of the students, is 0.55 points higher than those who are not, but this does not apply to school accreditation. A school with good accreditation does not guarantee that students will get better mathematics literacy scores, as well as, the completeness of learning facilities in schools is not a factor upon better students toward their mathematics literacy score.

In addition, the study showed that there is an interaction between the easiness of access to the use of digital devices in schools and the completeness of learning facilities in schools. It means that the effect of the easiness of access to the use of ICT in schools on mathematics literacy scores depends on the completeness of learning facilities in schools. The scores increased by 2.16 points for that.

On the other hand, the interaction of the teacher certification and the use of ICT for education do not affect the mathematics literacy score, in line with the interaction between the use of digital devices for education and the completeness of learning facilities in schools as well as the interaction between the use of ICT for education and school locations has a negative effect on mathematics literacy score.

Table 3. Result of Analysis of HLM

	MAT			MAT			MAT			MAT			MAT		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	39.45	39.23 – 39.67	**<0.001**	31.96	31.16 – 32.75	**<0.001**	31.79	30.63 – 32.95	**<0.001**	31.92	30.76 – 33.09	**<0.001**	31.37	29.97 – 32.78	**<0.001**
Socioeconomic index				2.53	1.90 – 3.16	**<0.001**	2.11	1.48 – 2.74	**<0.001**	2.07	1.44 – 2.70	**<0.001**	2.06	1.43 – 2.69	**<0.001**
The number of smartphone				0.80	0.68 – 0.92	**<0.001**	0.77	0.65 – 0.89	**<0.001**	0.77	0.65 – 0.89	**<0.001**	0.77	0.44 – 0.78	**<0.001**
The number of computer				0.65	0.48 – 0.83	**<0.001**	0.63	0.46 – 0.80	**<0.001**	0.62	0.44 – 0.79	**<0.001**	0.61	0.54 – 1.04	**<0.001**
Availability of ICT at home				0.27	0.17 – 0.37	**<0.001**	0.28	0.18 – 0.39	**<0.001**	0.29	0.19 – 0.39	**<0.001**	0.29	0.19 – 0.39	**<0.001**
Availability of ICT at school				0.31	0.20 – 0.42	**<0.001**	0.34	0.22 – 0.45	**<0.001**	0.34	0.23 – 0.45	**<0.001**	0.34	0.23 – 0.45	**<0.001**
The easiness of access to use of digital devices				-0.79	-1.46 – -0.12	**0.021**	-0.87	-1.54 – -0.20	**0.011**	-0.88	-1.55 – -0.21	**0.010**	-1.74	-2.81 – -0.68	**0.002**
ICT for education				1.23	0.76 – 1.71	**<0.001**	1.13	0.66 – 1.60	**<0.001**	1.13	0.66 – 1.60	**<0.001**	4.55	2.58 – 6.51	**<0.001**
Benefit of ICT in daily life				3.36	2.72 – 4.00	**<0.001**	3.30	2.67 – 3.94	**<0.001**	3.28	2.64 – 3.91	**<0.001**	3.28	2.64 – 3.92	**<0.001**
School location							0.54	0.38 – 0.70	**<0.001**	0.55	0.39 – 0.71	**<0.001**	0.55	0.39 – 0.71	**<0.001**
Teacher certification							0.33	0.10 – 0.57	**0.005**	0.32	0.09 – 0.55	**0.007**	0.55	0.26 – 0.84	**<0.001**
School accreditation							-0.68	-0.92 – -0.44	**<0.001**	-0.75	-1.00 – -0.51	**<0.001**	-0.50	-0.81 – -0.21	**0.001**
Completeness of facilities							-0.88	-1.47 – -0.29	**0.003**	-0.88	-1.48 – -0.27	**0.004**	-1.64	-3.02 – -0.26	0.020
ICT for education* teacher certification													-0.70	-1.28 – -0.11	**0.020**
ICT for education * school accreditation													-0.75	-1.35 – -0.16	**0.013**
Easiness of access * facilities													2.16	0.1 – 4.17	**0.034**
ICT for education * easiness of access													-2.00	-3.45 – -0.55	**0.007**
Random Effects															
σ^2	37.66			36.82			36.74			36.74			36.68		
τ_{00}	12.87 School			8.67 School			7.86 School			18.56 School			33.24 School		
τ_{11}										0.00 Teacher certification			1.72 Teacher certification		
										2.40 School accreditation			2.69 School accreditation		
										13.49 School indeks_8sch			7.74 School indeks_8sch		
ρ_{01}										1.00			-0.73		
										-0.75			-0.81		
										-0.49			-0.79		
ICC	0.25			0.19			0.18						0.18		
N	1414 School			1414 School			1414 School			1414 School			1414 School		
Observations	13079			13079			13079			13079			13079		
Marginal R^2 / Conditional R^2	0.000 / 0.255			0.058 / 0.238			0.090 / 0.251			0.108 / NA			0.092 / 0.253		

Determining the Effect of ICT Literacy on Mathematics Achievement

In the precedent study, inconsistent results have been reported for gender. Many studies reported that female students have significantly higher ICT literacy than male students do (Ainley et al., 2010), whereas some studies showed that male students have a more positive attitude than female students. Our study found that gender was not statistically significant in affecting mathematics scores in AKSI 2019.

On the other hand, ICT availability at home was found to be negatively affected by mathematics, reading, and science achievement, which aligns with previous research (Lee & Wu, 2012), and student ICT availability at school was found to have no correlations with student mathematics, reading, and scientific literacy (Hu et al., 2018). On the contrary, our study revealed that the availability of IT at home and school has a significant effect on mathematics literacy scores. In addition, the number of smartphones and computers per student had a positive effect on mathematics literacy scores.

In some countries, access to ICT and the internet is provided to students with the intention of providing ICT-based learning opportunities to a greater extent than for personal uses. Interestingly, in PISA 2003, Organisation for Economic Co-operation and Development (2005) found that access to a computer at home had the largest impact on mathematics literacy (the major domain for PISA 2003). Therefore, computer accessibility was included as a predictor in the current study. Meanwhile, in our study, the easiness of access to the use of digital devices in schools has a negative effect on mathematics literacy scores.

In terms of ICT usage, in Korea, the more students used computers for study or assignment, the more likely they were to attain lower levels instead of super-ordinate levels of ICT literacy, which suggested that computer usage for study in Korea is not strongly related with ICT literacy (Kim et al., 2014), which aligns with the research conducted by Hu et al. (2018) that integrating ICT into education is to facilitate student learning, the negative relationship between either student ICT academic use at school or outside school and their learning outcomes deserve serious attention.

The results might indicate that ICT was not used in a satisfactory approach to enhance student learning. In contrast, in our study, it is revealed that using ICT for education can increase mathematics literacy score, in line with Plumm (2008) that the way in which students use ICT for educational purposes may relate to achievement.

With a large variety of software and Internet applications accessible to students, some may be more beneficial to learning, while others may require more skill. ICT leisure use outside school was positively associated with reading and scientific literacy but had no significant correlations with mathematics scores (Hu et al., 2018). Similarly, in this study, the usage of ICT for entertainers did not significantly impact mathematics scores. With regard to the usage of IT in daily life, it can significantly affect mathematics literacy scores.

Regarding school level, students who go to schools located in a region with relatively high accessibility to information tend to have a high ICT literacy level and get better mathematics scores. In the study, teacher certification, which is one of the administrative requirements for teacher professionalism, has a significant impact on mathematics literacy score, similar to studies conducted by Suci and Mayangsari (2017) that there is a significant influence between teacher certification on student achievement in SMKN 7 Pandeglang. Jamaliah and Cahyaningsih (2020), in their literature review, found the same results that certified teachers had a positive impact on student achievement.

On the other hand, Sukarti (2013), in her study, showed that there are non-significant differences between the learning outcomes of students taught by certified teachers and students taught by a non-certified teacher. Furthermore, a study conducted by Siswandoko and Suryadi (2013) revealed that the analysis indicated that the teachers' certification has hardly ever been able to promote certificate holders' competencies. The study found out that the student's learning achievement was determined more by the social-economic status of the students' families rather than by the actual certification mechanism.

School accreditation is an indicator of improving the quality of education in order to achieve quality standards of education. In this study, it was included as a variable that is assumed to affect the mathematics literacy score in AKSI 2019. However, the result of the study found that accreditation has a negative impact on mathematics scores, which means that it is not influenced by school accreditation. Align with a study conducted by Samad and Mangindara (2019)

in 8th grade in Gowa, the result of the study revealed that there is no effect of school accreditation on student learning outcomes, but there is an influence of learning models on student learning outcome. In contrast, Mairing (2016) found that better school accreditation would have an impact on learning outcomes, especially in mathematics.

Regarding school infrastructure, the interaction between the easiness of access to the use of digital devices in schools and the completeness of learning facilities in schools has an influence in increasing students' mathematics literacy scores. In addition, the higher the satisfaction level of students in school classes using ICT, the higher was the mathematics score of the students, which implied that ICT using classes should be efficiently provided in school. However, the interaction between ICT use for education and school locations has a negative effect on mathematics scores, contrary to our expectations.

CONCLUSION

Based on the research findings and discussion, it is concluded that the social-economic status of students (SES) affects the achievement of students' mathematics literacy scores. Students with good social-economic status have higher mathematics literacy scores than students who had not. Students with good social-economic status have a better smartphone or computer access. This is in contrast to the easiness of ICT access in schools which decreased by 1.74 points. It means that students' access to ICT in schools does not guarantee that students' mathematics literacy score is better. Apart from social-economic factors, other variables such as school position also have an effect on mathematics literacy scores. They need guidance for schools that are far from the city. The achievement of the mathematics literacy score of students who are in these schools is lower. Coaching also includes teacher certification. The more certified teachers in the school have a positive impact. This is in contrast to school accreditation, which has taken a large portion as a determining variable for student success. In fact, schools with good accreditation do not always contribute positively to student achievement in mathematics literacy scores. Concerning gender, research shows that there is no significant relationship between gender and achievement in mathematics literacy scores.

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