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Mathematical Literacy Skills for Elementary School Students: A Comparative Study Between Interactive STEM Learning and Paper-and-Pencil STEM Learning

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Abstract: This study aimed to compare and examine the effectiveness of interactive STEM learning and paper-and-pencil STEM learning in terms of mathematical literacy skills of elementary school students. This research is of a quasi-experimental type with a non-equivalent pretest-posttest control group design. Sampling was carried out on the elementary school populations in Bengkulu and South Sumatra Provinces in two stages. In the first stage, schools in rural and urban areas were selected, and in the second, classes in each school were randomly selected. The selected sample consisted of fifth-grade students of the Public Elementary School of Terawas, Musi Rawas, with an experimental class A (n = 20) and an experimental class B (n = 19), as well as fifth-grade students of the Public Elementary School of Bengkulu City, with an experimental class A (n = 25) and an experimental class B (n = 22). Data collection was conducted using mathematical literacy skills tests in reference to the PISA and Minimum Competency Assessment (level 1–3). Data analysis was performed using descriptive and inferential statistics; it employed an independent t-test for the comparative testing and an N-gain test for testing the effectiveness of STEM learning. The results showed that there were differences in math literacy skills between interactive STEM and paper-and-pencil STEM for students in urban schools, but not significantly different for students in rural schools. General STEM learning was effective in increasing the literacy of elementary school students, and interactive STEM in particular demonstrated the highest level of effectiveness in the urban school.

Keywords: *Experimental research, interactive STEM, mathematical literacy, paper and pencil STEM.*

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Introduction

The demands of learning outcomes in the 21st century require students to have abilities in technology, media, and information, as well as innovation (Partnership for 21st Century Skills, 2014); they require critical thinking, creative thinking, communicative, and collaborative skills in students (Nahdi, 2019; Trilling & Fadel, 2009), metacognition empowerment (Muhali, 2019), and technological integration in learning (Shafie et al., 2019). These demands are of particular concern in the implementation of education. This is because there are no boundaries between countries in terms of communication and cooperation. As a result, all disciplines must anticipate this situation (Sirajudin et al., 2021).

In Indonesia, the government has consistently made efforts to improve the quality of learning outcomes from elementary school to tertiary education levels. The 2013 Curriculum has been implemented with an emphasis on thematic scientific learning (Ministry of Education and Culture, 2014). Competency standards at the elementary school level are focused on literacy and numeracy competencies. In addition, the government also adjusted learning evaluation through the Minimum Competency Assessment to the TIMSS and PISA levels. This requires special attention to the literacy skills development of students from an early age, e.g., from the elementary school level.

Mathematical literacy is the ability to identify, interpret, formulate, solve problems, and communicate mathematical concepts in various everyday contexts (Adeyemi & Adaramola, 2014; Geiger et al., 2015; Ojose, 2011; Organisation for Economic Co-operation and Development [OECD], 2013, 2014; Stacey & Turner, 2015). Mathematical literacy is an important learning goal at the elementary and secondary school levels. Mathematical literacy is a basic skill that must be owned and mastered by students in every region today (Ahyan et al., 2021). Students' skills in solving everyday problems

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will be better if they have good mathematical literacy skills (Geiger et al., 2015). In addition, good literacy skills affect the development of each individual's thinking skills (Pantiwati et al., 2022). The literacy process will increase one's sensitivity to numbers and arithmetic communication in solving everyday problems (Manolitsis et al., 2013).

However, especially in Indonesia, the performance of student outcomes achievement has been low. Periodic surveys by international and national institutions related to student literacy achievement yielded results in the low category. According to literacy-measuring PISA test results, Indonesia has been ranked among the bottommost with an average score in a low category (OECD, 2019). At the elementary school level, a similar assessment, namely TIMSS, showed that in the field of mathematics, Indonesian students had low ratings (Mullis & Martin, 2017). These data are also supported by the results of the Minimum Competency Assessments (MCA) at the elementary school level in Indonesia in 2021 and 2022, showing that less than 50% of Indonesian students reached the minimum competency limit for Mathematical literacy (Center for Educational Assessment of the Ministry of Education and Culture, 2022).

Low mathematical literacy can be influenced by the abilities of the educator and the student and by the learning model used (Jehlicka & Rejsek, 2018). Increasing literacy at the basic level is not the same as it is at the middle and high levels, given that the elementary school stage is important in personality and critical thinking skills development (Agnihotri et al., 2021). Research trends in recent years show that the use of technology in learning has an important role in learning outcomes achievement. The application of digital media and technology can accelerate the increase in knowledge (Wijaya et al., 2016). As an alternative solution to literacy problems in elementary schools, science, technology, engineering, and mathematics (STEM) learning can be implemented in students. STEM learning goes hand in hand with developments in the 21st century and the global economy (Bybee, 2010). Learning planning that integrates 21st century competencies will result in better knowledge construction (Stehle & Peters-Burton, 2019). Teachers, in developing students' abilities, need to carry out innovative learning (Susanta, Koto et al., 2022). Teachers need STEM education that fits the contexts and daily lives of students (Thingwiangthong et al., 2021).

The incorporation of STEM in learning can activate scientific skills and encourage the use of technology (English & King, 2015). STEM motivates students in learning (Chittum et al., 2017), drives education reforms (Blackley & Howell, 2015), increases understanding of concepts (Sandi, 2021), and helps students become better at communication and collaboration in class (Han et al., 2016). Several other research studies have also proven the impact of STEM on classroom learning. STEM supports creativity in solving challenging problems (Barry et al., 2018) and in actualizing concepts (Estapa & Tank, 2017). The application of STEM emphasizes innovation, creativity, and higher-order thinking skills (Kurup et al., 2019; Putra & Indriani, 2017). It also improves critical thinking and problem-solving (Astuti et al., 2021). Students can associate learning with their real lives (Sutaphan & Yuenyong, 2019).

Other research studies also proved that STEM impacts students' literacy skills. Among them, the research conducted by Yıldırım and Sidekli (2018) showed that STEM education has a positive effect by increasing students' mathematical literacy. Through the application of STEM, there is a consistent increase in literacy skills (Stipek et al., 2010). Many STEM research studies on literacy have been carried out, and they proved that STEM methods are better than non-STEM or conventional learning (Mujib et al., 2020; Sagala et al., 2019). Furthermore, the use of STEM online has an impact on students' abilities (Evagorou & Nisiforou, 2020).

The studies that we have described above form a basis for us to test the impact of technology on learning through the application of STEM. The fact that Indonesia is one of the countries affected by the COVID-19 pandemic, especially in education, also motivated this review. Changes in the learning system require the use of technology to ensure education process continuity. Post-COVID-19 learning still requires the use of technology and information. In line with this, the Indonesian government, to improve the quality of education, is implementing a school digitalization program (Ministry of Education and Culture, 2019). However, not all schools are equally prepared, which has a significant impact on learning outcomes. We conducted this research to examine the effectiveness of interactive STEM learning and paper-and-pencil STEM learning in rural and urban schools as well as to compare literacy skills achieved through the application of STEM. In our opinion, this needs to be done, especially for school students in rural and urban areas. Therefore, there are two research questions examined in this study, namely:

1. Are there differences in mathematical literacy skills between interactive STEM learning and paper-and-pencil STEM learning for students in urban schools?
2. Are there differences in mathematical literacy skills between interactive STEM learning and paper-and-pencil STEM learning for students in rural schools?

Literature Review

Elementary School Students' Mathematical Literacy

The mathematical literacy of elementary school students in Indonesia has become the most important research topic in the last five years, which has not only focused on students' abilities but also the learning process in supporting literacy (Hapsari et al., 2022). Mathematical literacy in PISA generally consists of the ability to process communication, mathematizing, representation, reason, and arguments, devise strategies for solving problems, use symbolic, formal, and technical language and operations, and use mathematical tools (OECD, 2013; Steen, 2002). This study in particular examined literacy skills at the elementary school level. In Indonesia, the cognitive levels of math-numeric literacy in the Minimum Competency Assessment are divided into three: knowing, applying, and reasoning (Wijaya & Dewayani, 2021).

Based on the results of the literature research, it was concluded that elementary school students' mathematical literacy abilities are at levels one, two, and three (Wijaya & Dewayani, 2021; Wijayanti & Anggraeni, 2020). In this study, elementary school students' mathematical literacy carries the indicators in Table 1.

Table 1. Literacy Level Indicators for Elementary School Students

Literacy level	Cognitive Level	Indicators of the Ability of Elementary School Students
Level 1	Knowing	Students can use their knowledge to solve routine problems and can solve problems in a general context.
Level 2	Applying	Students can carry out procedures well in solving problems and choose and apply simple problem-solving strategies.
Level 3	Reasoning	Students can work effectively with models, select and integrate different representations, and then relate them to the real world.

(Ministry of Education, Culture, Research, and Technology, 2021; Wijaya & Dewayani, 2021)

Urban and Rural Schools

In the study of rural and urban schools, of course, there will be differences, especially in terms of the use of technology and information. Urban and rural areas are different from a technological point of view, where rural areas are technologically backward compared to urban areas, and urban schools are more developed (Jošic et al., 2022). According to the TIMSS, the sizes of the education populations in cities and villages are different (Mullis & Martin, 2017). For the study of education systems in cities, there is more information available, coupled with the worldwide presence of the Internet today. It is not the case in villages, however, where the conditions may be opposite (Mahdalena & Handayani, 2020).

Several research studies have empirically proven differences in learning outcomes between students from urban and rural schools. The research by Khusaini and Muvera (2020) showed that schools in urban areas are superior to rural schools based on student achievement and parental characteristics. In another study, rural school students did not show high engagement in mathematics compared to urban school students (Ayub et al., 2017).

STEM in Elementary School Learning

Mathematics in elementary schools is separated from other subjects although, according to the 2013 Curriculum, learning is carried out thematically. One reason is the lack of mathematics teaching materials that can be combined with other materials (Firdaus et al., 2020). Empirical evidence shows that STEM learning designs are suitable for elementary school students. Using a thematic, integrated approach, STEM is important in elementary mathematics learning. Competence in STEM (science, technology, engineering, and mathematics) is becoming increasingly important today (OECD, 2019). Several STEM motivational interventions have successfully initiated positive student changes (Shin et al., 2022), showing that STEM application is important in elementary school learning.

STEM places an increasing emphasis on technology in school programs (Bybee, 2010). This is driven by the demands of the times that technology is present in the field of education. In applying STEM creative teaching, it is important to involve and motivate students (Barry et al., 2018). As a teaching method, STEM can stimulate children's learning interests and improve children's comprehensive abilities in mathematics (He et al., 2021). The goal of STEM education is for students to have scientific literacy skills and ICT knowledge (Indrasari et al., 2020).

Interactive STEM Learning

As shown by empirical evidence, interactive learning designs have seen wide applications. Developing strategies for interactive teaching materials can improve children's visualization literacy (Alper et al., 2017). Interactive learning that is presented interestingly will almost certainly have a positive impact by improving the quality of education (Latifah et al., 2020). Considered important in online learning are interactions with online content, interactions with remote instructors, and interactions with remote peers (Abouhashem et al., 2021). Interactive teaching materials in STEM can be applied. Mathematics achievement through STEM is realized with a combination of technology and engineering (Acar et al., 2018).

Online teaching materials help teachers and students access knowledge easily and effectively, promote digital literacy, and motivate students (Kefalis & Drigas, 2019). Other findings conclude that interactive STEM-based digital e-books can improve students' scientific literacy skills (Yuberti et al., 2022). The use of interactive teaching materials is impactful to the achievement of students' thinking skills. The research by Susanta, Sumardi et al. (2022) found that modules designed to be interactive encourage students to improve their mathematical literacy skills.

Methodology

Research Design

This research is a quasi-experiment with a quantitative approach. The quantitative approach described the actual results of the subject (Creswell, 2014). This approach is in accordance with the research objective, namely to compare the literacy skills of elementary school students between interactive STEM-based learning and STEM-based paper and pencil for students in urban and rural areas. Interactive STEM learning treatment is learning using online materials (E-Worksheets STEM) where students obtain material from interactive videos and carry out evaluations online. The paper and pencil STEM treatment in this study was students working on printed STEM worksheets manually. The research used the pretest-posttest non-equivalent group design.

Table 2. Research Design

Group	Pretest	Treatment	Posttest
Experiment A	O1A	X1	O2A
Experiment B	O1B	X2	O2B

O1A: the pretest result of experimental group A; O1B: the pretest result of experimental group B; X1: interactive STEM learning treatment; X2: paper-and-pencil STEM learning treatment; O2A: the posttest result of experimental group A; O2B: the posttest result of experimental group B.

The implementation of the research was carried out by giving a pretest to the two research classes as a reference for students' initial abilities. The treatment in each class is designed based on the stages and interactive STEM and STEM paper and pencil teaching materials. Comparison of treatment between interactive STEM and paper-and-pencil STEM learning in Table 3.

Table 3. Treatment in the Research Class

Aspect	Interactive STEM learning	Paper-and-pencil STEM learning
Time	Pretest: 2 × 35 minutes Lesson: 4 × 35 minutes Postest: 2 × 35 minutes	Pretest: 2 × 35 minutes Lesson: 4 × 35 minutes Postets: 2 × 35 minutes
Learning Steps	a) The teacher explains the objective and learning process b) Learning process: using E-worksheets which is presented with interactive materials, videos, and interactive quizzes c) Conduct evaluation	a) The teacher explains the objective and learning process b) The learning process: using printed worksheets and students complete them on sheet worksheets c) Conduct evaluation
Lesson plan	The lesson plan is prepared based on the stages and instructions for using the E-Worksheets which consists of four meetings with material on the perimeter and area of flat shapes.	The lesson plan is prepared conventionally consisting of four meetings on the use of printed worksheets with material on the perimeter and area of flat shapes.
Teacher	As a facilitator	As a facilitator
Students	Work online	Work with paper and pencil

Sample and Data Collection

The participants in this study were selected using purposive sampling technique which was in accordance with the research objectives to analyze STEM treatment at schools in rural and urban areas. We chose schools in Bengkulu City and Musi Rawas Regency as a sample. After selecting two school locations, a simple random sampling technique was carried out, where each school was given an equal opportunity. The schools selected were the Public Elementary School of Terawas, Musi Rawas, and the Public Elementary School of Bengkulu City. Experimental groups were determined for each selected school. The selection of the study group was carried out randomly from the intact class group at each school. We present the selected sample of the study in Table 4.

Table 4. Research Sample

Group	Group Size	Experiment A	Experiment B
Rural	39	20 students (M=10; F=10)	19 students (M=7; F=12)
Urban	47	25 students (M=9; F= 16)	22 students (M=10; F= 12)
Total	86	45	41

In this comparative experimental research, data were collected in the form of pretest and posttest data through mathematical literacy tests. The pretest was administered before the treatment was applied to the experimental groups to measure students' initial mathematical literacy abilities. After giving treatment to each experimental group, a posttest was carried out.

Research Instrument

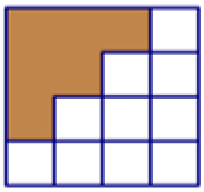
The instrument in this study referred to the research objective, namely, students' mathematical literacy abilities. This research test instrument was prepared to refer to three cognitive levels, knowing, application, and reasoning. We took into account the selection of this level based on the ability characteristics of elementary school students and the demands of the Minimum Competency Assessment goals in Indonesia. The mathematical literacy test instrument in this study is shown in Table 5.

Table 5. Research Instrument

Literacy level	Cognitive Level	Item No.	Total Item
Level 1	Knowing	1, 4, 7, 10	4
Level 2	Applying	2, 5, 8, 11	4
Level 3	Reasoning	3, 6, 9, 12	4

The knowing level aims to measure students' basic knowledge and understanding of material related to mathematical objects. Applying level measures students' ability to apply knowledge in solving problems. The reasoning level aims to assess students' reasoning abilities in analyzing data and information and making conclusions. An example of an instrument in this study is shown in Figure 1.

One of the *tabut* buildings on the side is a square shape decorated with origami paper in the shape of a small square measuring 10cm x 10cm. After being decorated by covering the surface of the *tabut* using 10 origami papers, it turns out that there are areas that have not been covered by origami paper as shown in the image below.



Questions:

a. How much more origami paper would you need to cover so that the entire large square is covered? (applying)
b. What is the area of the large square? (knowing)
c. How many squares were in the picture before they were all covered? (reasoning)

Figure 1. Example Questions (Translated From Bahasa Indonesia)

The assessment of each item used the following criteria: (a) score 3 if the answer was correct and complete, (b) score 2 if the answer was inaccurate and incomplete, and (c) score 0 if the answer was wrong or if no answer was given. The instrument had been tested for validity by experts and had been subjected to empirical tests involving 24 fifth-grade elementary school students. The logical validity was measured with the Aiken index, with a criterion limit for validity being .50 (Aiken, 1980). Meanwhile, the empirical tests were conducted with product-moment correlation tests using SPSS 23. The results of the logical and empirical validity tests are summarized in Table 6.

Table 6. Research Sample

Instrument Level	Item Number	Aiken Index	Total Correlation Item	Conclusion
Level 1	1, 4, 7, 10	.675– .715	.675– .802	Valid
Level 2	2, 5, 8, 11	.545– .704	.720– .832	Valid
Level 3	63, 6, 9, 12	.526– .790	.603– .768	Valid

Based on Table 6, all questions were considered valid for having Aiken index values greater than .5. This indicates that the research instrument is logically feasible and has a high construct relationship (Nieveen, 1999). The empirical test results also showed a high correlation value with a Cronbach's alpha value of more than .6. In proving the reliability of the 12 literacy test instrument items, we also conducted a reliability analysis using Cronbach's alpha formula, yielding a calculation value of .72 (high criterion) (Basuki & Hariyanto, 2014), with a standard error measurement (SEM) value of .058.

Data Analysis

The data analysis method consisted of descriptive and financial statistics. The descriptive statistical analysis provided an overview of students' mathematical literacy abilities data, such as average, maximum, minimum, and standard deviation values. The inferential statistical analysis aimed to test the research hypothesis, i.e., differences in mathematical literacy abilities of students undergoing interactive STEM learning and paper-and-pencil STEM learning. The analysis with an independent t-test was assisted by the SPSS software with a 95% confidence level. In analyzing the effectiveness of each experimental group we used an N-gain test with pretest and posttest data based on the equation from Hake (1998) with the following criteria: high ($g \geq .7$), medium (score $.3 \leq g < .7$), low ($g < .3$).

Findings

Description of Research Results

The application of STEM was effective in improving the mathematical literacy abilities of elementary school students. The following describes the comparative test results between interactive STEM learning and paper-and-pencil STEM learning in rural and urban schools. To prove that the data used came from groups with homogeneous abilities and to ensure that the effects of the treatment could be observed, we carried out a pretest. The results of the pretest data homogeneity test are shown in Table 7.

Table 7. Pretest Data Description

Schools	Experimental Groups	N	Mean	Std. Deviation	Levene's Test for Equality of Variances		t-Test for Equality of Means		
					f	Sig.	t	df	Sig.
Rural	Experiment A	20	37.91	10.16	.08	.77	.24	37	.808
	Experiment B	19	38.74	10.85					
Urban	Experiment A	25	42.55	8.36	.14	.70	.37	45	.715
	Experiment B	22	41.66	8.17					

As shown in Table 7, the comparative test with the parametric independent t-test at a 95% confidence level yielded sig. values greater than alpha (> .05). It was then concluded that there was no difference in initial literacy abilities between the treatment class students in rural and urban schools. Since the significance values were greater than alpha (α = .05), the statistical test accepted the null hypothesis, which states that there is no difference in students' initial abilities between research classes. This statistically guarantees that the classes were homogeneous. Therefore, the impact of the treatment could be measured.

After the administration of interactive STEM treatment in the first experimental class and paper-and-pencil STEM treatment in the second, a literacy ability posttest was carried out. The results of the analysis of students' abilities based on the level of students' mathematical literacy post-treatment are shown in Table 8.

Table 8. Posttest Data Description

Experimental Groups	Rural				Urban			
	X_{min}	X_{max}	$\bar{X}$	Std.	X_{min}	X_{max}	$\bar{X}$	Std.
Interactive STEM	58.33	80.56	66.75	5.29	61.11	83.33	74.94	6.11
Paper-and-pencil STEM	58.33	75.00	64.11	4.82	58.33	75.00	65.11	5.62

The data in Table 8 show that the literacy of students who were undergoing interactive STEM learning was higher than the literacy of those undergoing paper-and-pencil STEM learning. The highest average scores were obtained by urban school classes. A further description of students' abilities based on each group's average mastery at each literacy level is provided in Figure 2.

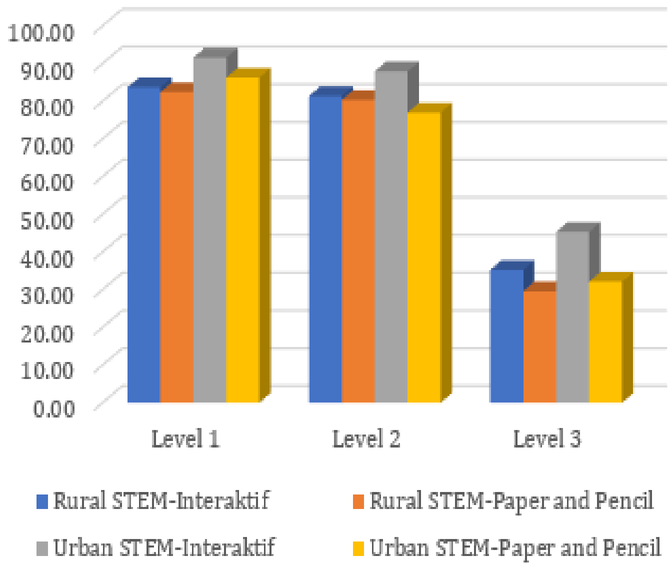


Figure 2. Students' Mathematics Literacy Levels

Figure 2 shows that, in general, students' mastery based on their answers to level 1 and level 2 questions was high. Meanwhile, at level 3, students' mastery was low. This illustrates that the students had yet to have good mastery at the application level.

Comparative Test of Students' Literacy Abilities

In carrying out a comparative analysis of students' mathematical literacy abilities in each research class, a parametric test (independent t-test) was used. Two minimum requirements must be met to reach that end: normality (Table 9) and homogeneity (Table 10). The normality test aimed to ensure that the data in the study were normally distributed. Normality testing was conducted with the Kolmogorov-Smirnov test under the following criteria: if p <.05, the data were not normally distributed; if p > .05, the data were normally distributed (Ozgul et al., 2018). The results of the data normality test are provided in Table 9.

Table 9. Normality Test Results

One-Sample Kolmogorov Test	Rural		Urban	
	Interactive STEM	Paper-and-Pencil STEM	Interactive STEM	Paper-and-Pencil STEM
N	20	19	25	22
Mean	69.305	67.690	72.778	66.665
Std. Deviation	5.291	4.460	6.107	5.621
Test Statistic	.131	.154	.127	.144
Asymp. Sig. (2-tailed)	.114	.202	.137	.200

Table 9 provides us with information that each data in the treatment group obtained a significance value of more than alpha (p > .05). This means that all pretest and posttest data in the treatment groups were normally distributed. The second prerequisite test conducted in the data analysis was Levene's homogeneity test, assisted with SPSS. The data would be considered homogeneous if the significance value exceeded .05 (see Table 10). Based on Table 10, the significance value obtained from Levene's test was more than alpha (p > .05). Therefore, it was concluded that the data had a homogeneous distribution. Since both prerequisite tests were fulfilled, the data were considered viable to be used in the hypotheses testing. The results of the comparative testing between interactive STEM learning and paper-and-pencil STEM learning in rural and urban groups are summarized in Table 10.

Table 10. Comparative Test (Independent t-Test) Results

Schools	Experimental Groups	N	Mean	Levene's Test for Equality of Variances		t-Test for Equality of Means		
				f	sig.	t	df	sig.
Rural	Interactive STEM	20	66.750	.295	.590	1.028	37	.311
	Paper-and-Pencil STEM	19	64.111					
Urban	Interactive STEM	25	74.944	.254	.617	3.552	45	.001
	Paper-and-Pencil STEM	22	65.111					

Table 10 shows that in the rural school, there was no significant difference between interactive STEM learning applications and paper-and-pencil STEM learning applications. The t-count value obtained at the 95% confidence level and 38 degrees of freedom were 1.028. As the t table value was 2.026, it means that t count < t table. It was also discovered that the significance value was greater than alpha (p>.05). Based on these results, the hypothesis proposed was rejected. In other words, there was no significant difference in literacy skills between the two treatment groups in the rural school. In the urban school, the tcount obtained was 3.552, which was greater than the ttable (2.014). Meanwhile, the significance value obtained was .001(p>.05). In conclusion, there was a significant difference between interactive STEM learning applications and paper-and-pencil STEM learning applications in an urban school.

STEM Learning Effectiveness Test

To find out about the effectiveness of the STEM model applied to each class, we conducted an N-gain test using pretest and posttest data. The average N-gain test results for each class are provided in Table 11.

Table 11. STEM Learning Effectiveness Test Results

Schools	Experimental Groups	N	N-Gain	Description
Rural	Interactive STEM	20	51.84%	Moderate
	Paper-and-pencil STEM	19	41.49%	Moderate
Urban	Interactive STEM	25	49.63%	Moderate
	Paper-and-pencil STEM	22	45.60%	Moderate

Based on Table 11, the application of STEM learning was moderately effective in increasing mathematical literacy skills in elementary schools. Meanwhile, interactive STEM learning was moderate. In other words, learning that used the interactive STEM model tended to be more effective in increasing students' mathematical literacy skills. Figure 3 and Figure 4 depict the increases in students' mathematical literacy skills from the pretest to the posttest.

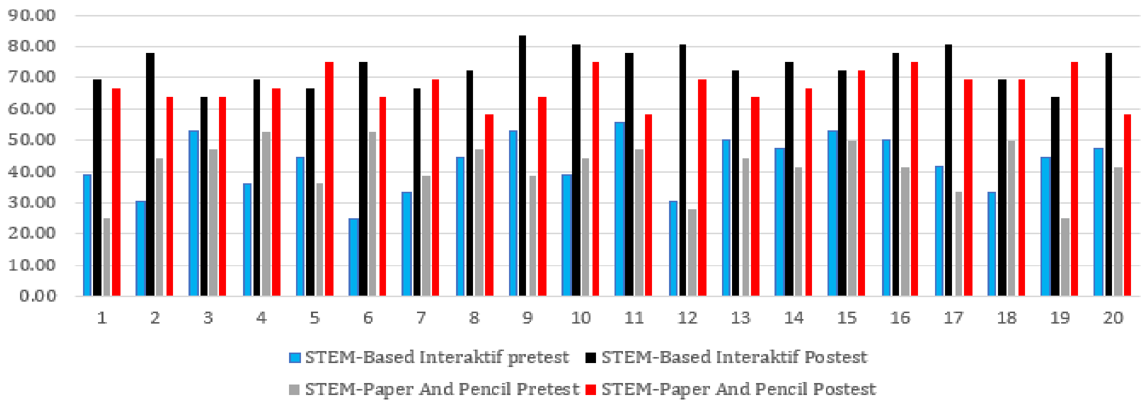


Figure 3. The Mathematical Literacy Pretest and Posttest Results of Urban School Students

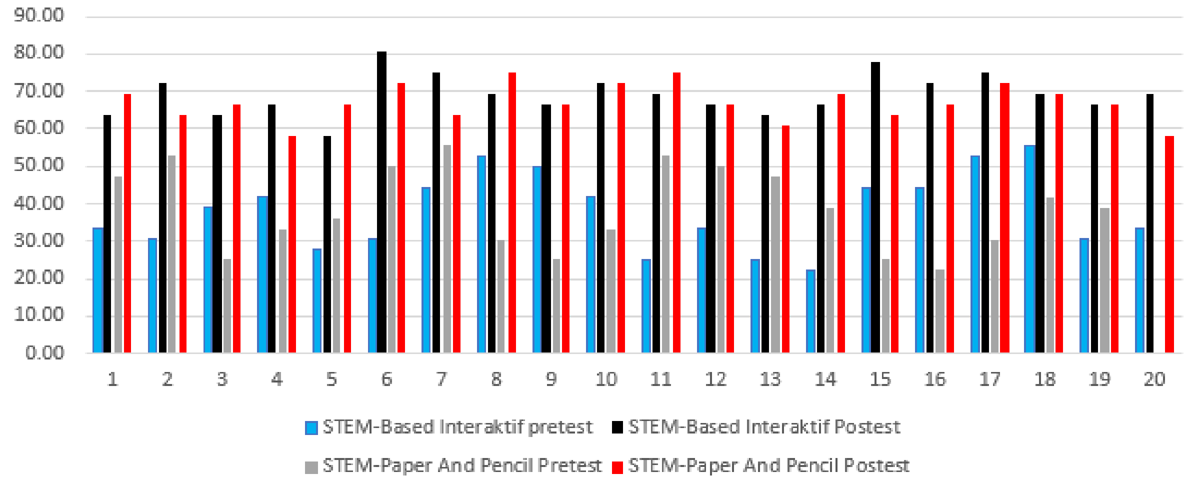


Figure 4. The Mathematical Literacy Pretest and Posttest Results of Rural School Students

Discussion

Students' Mathematical Literacy Abilities

The results of the study revealed that elementary school students in urban and rural areas tended to have good mastery at level 1 and level 2. However, their mastery at the reasoning level (level 3) was at a rate of less than 40.00%. In general, the mathematical literacy abilities of elementary school students as reflected by their answers to questions measuring reasoning were low. Analysis results showed that in answering level 3 mathematical literacy questions, most students only wrote down the information that they derived from the questions but did not determine the appropriate mathematical modeling of the problem and the solution. Some previous research that measured students' mathematical reasoning abilities showed that Indonesian students' reasoning abilities were low (Himawan et al., 2020; Widarti & Winarti, 2019). The research conducted by Susanto et al. (2023) found that the ability of junior high school students in Bengkulu City to solve reasoning-measuring Minimum Competency Assessment problems was still low. In line with the results of the evaluation carried out by the government, this asserts the need for literacy socialization in schools. As reflected by the research findings of Rakhmawati and Mustadi (2022), no literacy movement has been appropriately implemented in schools.

As indicated by the analysis results, the average literacy abilities of students in the urban area were higher than those in the rural area. This shows that the school in the urban area was better prepared than its rural counterpart especially in receiving information related to the Minimum Competency Assessment administered in Indonesia. In addition, easier access to information in the urban area than in the rural area made it easier for students and teachers alike to access literacy-based questions on the Internet. It is in line with Jošic et al. (2022) opinion that urban and rural areas are different in terms of technological aspects, where rural areas are technologically more backward than urban schools.

Mathematical Literacy in Interactive STEM Learning and Paper-and-Pencil STEM Learning

The results of this research show that in the urban school, there was a significant difference in the literacy abilities of students undergoing interactive STEM learning and those undergoing paper-and-pencil STEM learning, but that was not the case in the rural school. This indicates that the application of interactive STEM learning had more impact on the urban school, where information technology resources and electrical power were more readily available than in the rural school. This should be taken into consideration when implementing the school digitalization program initiated by the Indonesian government.

The average mathematical literacy abilities of students to whom the interactive STEM treatment was given were higher than those of students who were learning with paper-and-pencil STEM. This shows that technology use in learning exerted a greater amount of impact than conventional methods. This finding is supported by several previous studies. Pambudi et al. (2018) found that ICT-based interactive learning media could improve students' mathematical literacy, while Nurcahyo (2020) found that interactive multimedia increased students' digital literacy. It was also discovered by Aritonang and Safitri (2021) that incorporating online media in blended learning had an impact on mathematical literacy. Meanwhile, Alper et al. (2017) figured out that interactive teaching materials could improve students' visualization literacy.

STEM Learning Effectiveness

It was found in this research that STEM application was effective in increasing the literacy skills of elementary school students based on minimum mastery criteria. The effectiveness test results are supported by the observation of the improvement that occurred after STEM learning. An N-gain score in the range of .3-.7 is considered moderate, and a score above .7 is considered high. The results show that in general, the effectiveness of STEM learning was in the moderate category, but in the case of the urban experimental group to whom the interactive STEM treatment was administered, it fell into the high category. This is supported by the research by Evagorou and Nisiforou (2020) which found that online-based STEM learning had an impact on students' literacy abilities.

In general, this research's results showed that STEM is effective in increasing students' mathematical literacy skills. In agreement with this, Mujib et al. (2020) have previously stated that the integration of STEM in learning can improve students' achievement and literacy in science, mathematics, and technology engineering. Other research results showed that STEM has a positive impact by improving mathematical literacy (Stipek et al., 2010; Yıldırım & Sidekli, 2018).

Further discussion based on research findings that we have done. In urban schools, students' mathematical literacy skills with the interactive STEM approach are higher than those with paper and pencil STEM. Through an interactive STEM approach, the learning process is more effective, students are active, and the learning process is more independent. On the other hand, in the application of the paper and pencil STEM approach students are limited with the available resources provided by the teacher and material that is only available in printed worksheets,

Another finding is that in the sample of rural schools, there is no significant difference between the experimental class and the control class. This is because students in rural areas are not used to using online learning resources. This shows that the habits of students in urban areas that are supported in the use of technology will be more supportive in developing literacy skills through interactive learning resources.

Conclusion

The results of this study proved that STEM learning is effective in improving elementary school students' mathematical literacy skills. From the comparative test results, it was found that in the urban school, there was a significant difference in literacy abilities between students who were undergoing interactive STEM learning and those who were undergoing paper-and-pencil STEM learning. However, in the rural sample, no significant difference was derived. In other words, the use of interactive STEM had more impact on literacy skills in the urban area. Based on such results, it is suggested that teachers should make adjustments to the teaching materials used, especially interactive teaching materials in the case of rural schools.

Recommendations

This research aimed to compare the impacts of interactive STEM and paper-and-pencil STEM involving a test sample from rural and urban schools. The observed targets were elementary school students adapted to level 3 of the Minimum Competency Assessment. It is recommended that further studies should observe middle and high school students as targets. In addition, an emphasis on the use of interactive media at every level of school is needed to allow students to adapt to the demands of the Industrial Revolution 4.0 Era.

Limitations

This research comes with a limitation in the inability of the data sources to represent all rural and urban schools. In this study, only two schools each representing rural and urban areas were used. Therefore, it is critical to increase the sample size. Another limitation came from the uneven application of technology in rural schools during the COVID-19 pandemic, which impacted the technology used in teaching examined in this study.

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