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The Effect of Applying Scaffolding Method on Students' Programming Abilities at Surakarta State Vocational School

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Abstract:

This research aims to determine the effect of applying the scaffolding method on the programming abilities of students at Surakarta Vocational School as measured by tests or programming ability tests. By using the scaffolding method, it is hoped that students' programming abilities will be better than conventional learning methods. The research used a quasi-experimental design with a pre-test and post-test control group design. In the research, the control class was not given treatment in learning activities, while the experimental class was given treatment in the form of a scaffolding method in learning activities. The research subjects were 72 class X students at a Vocational School in Surakarta obtained by cluster random sampling. Research data was obtained using pre-test and post-test which were prepared based on basic programming concepts using the Java programming language. Research data analysis was carried out using descriptive analysis techniques using the SPSS application. The results of the research show that the application of the scaffolding method has a good effect on the programming abilities of students at Surakarta Vocational School. This can be seen from the average programming ability test result for the experimental class which is higher than the control class (79.58 > 74.72). Additionally, the gain score analysis revealed that the improvement in the experimental class (49.72%) was significantly higher than the control class (41.94%). It can be concluded that the programming ability of the experimental class using the scaffolding method is better than the control class.

Keywords: *Learning Outcomes, Programming Ability, Scaffolding Method*

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Introduction

In 2021, the Ministry of Education and Culture issued the Merdeka Curriculum policy as a recovery after the COVID 19 pandemic, where learning activities are centered on students (Aprima & Sari, 2022). In the independent curriculum, Information and Communication Technology (ICT) subjects at K-13 were changed to Informatics subjects which will begin to be taught at junior high school level (Barlian et al., 2022). Algorithms and Programming (AP) is one of the eight elements in the Informatics subject. Algorithm and programming elements discuss solutions to programming problems and convert these solutions into programs that can be executed by a computer. The learning objective of algorithm and programming elements is that students are expected to be able to develop a structured program using algorithm notation or other notation (Wahyono et al., 2021). The Informatics subject at Surakarta Vocational School is an obligation for class X students. The results of the author's informal interviews with several teachers in class X Informatics showed that programming learning activities were carried out using the Java programming language.

Java is a programming language that uses the OOP (Object-Oriented Programming) paradigm, which means that a program in the Java language will contain objects and classes in its lines of code. To write a simple program in Java, it must be based on the basic principles of OOP (Osisikankwu et al., 2015). Learning an OOP language like Java, especially for beginners who have never studied programming, can be a daunting task. Because apart from them needing to learn structured programming concepts and skills, which are used for code written in Java methods, they also need to understand object-oriented programming concepts such as classes, methods, and abstractions (Zhang et al., 2020). Based on observations that researchers have made, programming learning activities still use conventional learning methods. Researchers feel that the learning methods that are still being applied are not appropriate to the student-centered curriculum. According to Cheah (2020), conventional learning methods are no longer suitable for use in OOP-based programming learning activities, this is because there are several better learning methods that can be used.

Based on the literature review that has been carried out by researchers, the scaffolding learning method is one of the learning methods that can be applied in basic programming learning activities. Wardana & Mayub (2022) describe scaffolding as a learning method in which students, with the help of teachers or peers, work through tasks that are beyond their reach. Scaffolding facilitates learning through the active participation of each student. At the beginning of the learning process, students receive support and guidance from the teacher to help motivate and focus students on learning activities. Educators provide support or motivation to students step by step so that students are able to participate in the learning process activities and achieve optimal learning goals (Sidin, 2016).

While scaffolding has been described in a number of educational settings to have positive effects on student outcomes, the vast majority of work has been done in mathematics, science or higher education (Chairani, 2015; Mamin, 2008; Nursanti, 2022; Urban-Lurain et al., 2004; Wardana & Mayub, 2022). In vocational schools relatively little attention is paid to introductory programming education, especially programming using Java Programming language, which serves as a foundation for object-oriented programming. There is some research focusing on scaffolding for programming courses in common (Salleh et al., 2018; Sidin, 2016). Still, they are not specifically using Java as their programming language. Further, this previous research has not satisfactorily explored the effectiveness of scaffolding in vocational education that is embedded with Merdeka Curriculum. Therefore, it is still a question as to whether scaffolding can promote students' beginning programming skills in vocational school. This research aims to fill this gap by examining the impact of scaffolding on students' programming skills in a programming course at a vocational school under the new Merdeka Curriculum. Based on the Merdeka Curriculum in the AP element, students are expected to be able to master OOP-based programming language activities and object-oriented programming concepts that students must understand to carry out simple tasks. Basic programming learning activities at Surakarta Vocational School still use conventional learning methods so that students' programming abilities as seen from student learning outcomes are still not optimal. So, the researcher wants to conduct research entitled "Application of the Scaffolding Method to Student Programming Abilities at Surakarta Vocational School."

Related Work

Research by Chairani (2015) aims to assess whether scaffolding learning methods can be applied in the process of learning mathematics. Based on the literature review conducted in this study, it was revealed that the use of scaffolding by teachers can help reduce students' learning difficulties in mathematics and in solving mathematical problems. The learning concept in constructivist theory emphasizes that students form understanding through their own thinking. The scaffolding method provided by teachers is not to solve students' problems, but as guidance or direction by linking students' difficulties in learning to enhance the development of students' potential abilities.

Research by Mamin (2008) aims to explore the implementation of scaffolding learning methods in the learning of the periodic table of elements. Based on the findings of the study, Mamin (2008) concluded that the implementation of scaffolding learning methods is effectively used by teachers in explaining concepts in the Periodic Table of Elements. The implementation of this method involves guidance, learning motivation, and attention to learners, which ultimately can achieve learning goals.

The purpose of the study by Sidin (2016) is to evaluate learning outcomes and student responses to the implementation of scaffolding strategies in web programming learning for grade 10 TKJ (Computer Network Engineering) students at SMK Kartika Wirabuana 1. Evaluation is conducted through pre-tests and post-tests. Test analysis results show that the scaffolding method helps students learn web programming. Research by Nursanti (2022) aims to evaluate the implementation of scaffolding learning methods in the process of learning mathematics. Based on the research results, it was found that at the end of cycle II, there was an increase in the average learning outcomes of students by 97.11%. In addition, student activities, based on observation results, also increased by 80.9%.

There are 4 studies reviewed in this research. Research by Chairani (2015) and Mamin (2008) focuses on the implementation of scaffolding learning methods, while research by Sidin (2016) and Nursanti (2022) focuses on the impact of implementing scaffolding learning methods on student learning outcomes. In research focusing on the implementation of scaffolding learning methods, there are differences between the studies by Chairani (2015) and Mamin (2008). Mamin (2008) research has more stages such as analyzing students' ZPD first and dividing students into several small groups in learning activities. In research focusing on the influence of scaffolding method application in learning activities, there is no difference in the research results by Sidin (2016) and Nursanti (2022).

Research Method

Design

The research question addressed in this study is whether there is a difference in students' beginning programming abilities between students taught using the scaffolding method and those taught using conventional instruction at Surakarta State Vocational School. In order to answer this question, this study employed a quantitative approach with a quasi-experimental research design. A pre-test and post-test control group are used to measure the abilities of the control and experimental classes before and after the treatment. The instrument used in this research consisted of 20 valid multiple-choice questions, selected from an initial set of 35 items after validity testing. Reliability testing using the Spearman-Brown formula. The pre-test is administered to both the control and experimental classes before the treatment. Subsequently, the experimental class undergoes a specific treatment using the scaffolding learning method, which began with a Zone of Proximal Development (ZPD) assessment to group students into teams of 4–5. The teacher provided four types of support: modeling (logic demonstrations), feedback (constructive criticism), hints (pointing out logic errors), and collaborative learning (peer tutoring). After the research period concludes, both classes are then subjected to a post-test to assess the final abilities of the participants. SPSS version 25 will be employed to analyze the data. Table 1 shows the research treatment scenarios.

Table 1. Research treatment

Group	Pre-test	Treatment	Post-test
Experiment	Q1	X	Q2
Control	Q1		Q2

Population and Sample

For the population and sampling, the researcher identified approximately 600 grade X students at a State Vocational School who were distributed across 10 majors and 23 classes. The researcher utilized a cluster random sampling technique to divide these students into clusters based on their majors. The basis for dividing the students by majors is to ensure that the experimental and control classes are not significantly different in terms of background conditions. After the researcher determined the clusters to be studied, they then selected two intact classes totaling 72 students to be the control group and the experimental group. As shown in Figure 1, the equivalence test using pre-test results yielded a Levene's Test significance value of 0.247, confirming that the variances were equal, with a subsequent independent sample t-test significance (2-tailed) of 0.174, indicating no significant difference in prior ability between the control group and the experimental group.

Independent Samples Test

	Levene's Test for Equality of Variances				
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	1.363	.247	1.374	70	.174
Equal variances not assumed			1.374	67.455	.174

Figure 1. Equivalence test on pre-test results

Data Collection Instrument

The measurement tool in this study is an objective written test, which is a test where students choose answers from provided options. One example of an objective written test is a multiple-choice test. The question grid of the test used for quantitative data collection in Table 2 is arranged based on the flow of programming learning objectives according to the Teacher's Informatics Guidebook (Wahyono et al., 2021), with limitations imposed due to the time constraints of the research.

Table 2. Programming skills test questions

Num	Question Concept	Item Questions
1	Variable Concept	1, 2, 3, 4, 5
2	Input-Output Concept	6, 7, 8, 9, 10
3	Expression Concept	11, 12, 13, 14, 15
4	Condition Concept	16, 17, 18, 19, 20, 21, 22, 23, 24, 25

5	Looping Concept	26, 27, 28, 29, 30, 31, 32, 33, 34, 35

Validity and Reliability

Before the developed instrument is used for data collection, its validity and reliability were tested to ensure that the data obtained with the instrument are valid and reliable. Following the validity testing, 20 of the 35 initial items were retained for data collection, while the 15 invalid items were discarded. Table 3 shows the result of validity testing.

Table 3. The validity of the programming skills test instrument

Item Questions	Description
1, 2, 5, (Variable Concept) 6, 9, 10, (Input-Output Concept), 12, 13, 14, 15, (Expression Concept) 18, 19, 21, 22, 25, (Condition Concept) 26, 27, 30, 32, 34, (Looping Concept)	Valid
3, 4, 7, 8, 11, 16, 17, 20, 23, 24, 28, 29, 31, 33, 35	Invalid

After the validity of each instrument is tested, the next step is to conduct a reliability test using *Spearman Brown* formula to determine whether the developed instruments can produce reliable data. With a significant level (α) of 5%, the r_{table} obtained is 0.4821. The instrument is considered reliable if the calculated value (r_{count}) is greater than the table value (r_{table}), and if the r_{count} is less than the r_{table}, then the instrument is considered unreliable. Based on the calculations performed, the calculated r_{count} is 0.7927; therefore, the research instrument is considered reliable. Based on the validity and reliability testing, a total of 20 valid questions were used as both pretest and posttest instruments with identical items.

Hypothesis

H_o: The application of the scaffolding method does not impact students' programming abilities at Surakarta state vocational school.
H_a: The application of the scaffolding method impacts students' programming abilities at Surakarta state vocational school.

To test the hypothesis, a t-test is conducted. With a significance level of 5% and degrees of freedom (df = n - 2), if the calculated t-value > the critical t-value from the table, then Ho is rejected and Ha is accepted. Conversely, if the calculated t-value < the critical t-value, then Ho is rejected and Ha is accepted.

Procedure and Treatment

The research in the control and experimental classes was conducted over 4 sessions of learning activities. In the first two sessions, both classes were given a pre-test to assess the initial abilities of the students. Based on the results of the pre-tests from both the control and experimental classes, none of the students have reached the Minimum Competency Standard score of 75.

During the learning process, the educator always begins the lesson by greeting the students, taking attendance, and leading a prayer throughout the research period. After that, the main activity follows, which is explaining the core material to the students. After presenting the material, the educator allows the students to ask questions about anything they do not understand or need further explanation. In the first meeting, the experimental class was not given any treatment because the researcher conducted an assessment of each student's Zone of Proximal Development (ZPD). The educator distributed worksheets (LKPD) to each student. When working on the worksheets, students completed them independently. If any instructions were unclear, students could ask the educator. At the end of the lesson, the educator and students discussed the completed worksheets. The teacher will start by giving minimal guidance and gradually provide full guidance depending on the students' abilities and needs. For completing the worksheets, students used the Java IDE Eclipse. In the first meeting, the topics covered were an introduction to algorithms and programming, the IDE, and input/output (I/O).

The second meeting was conducted in the experimental classroom because Laboratory 1 at School was used for teacher activities during the second week of the research. The topics covered in the second meeting were variables, data types, and operators. After presenting the material, the educator distributed worksheets to the students. To complete the second meeting's worksheets, students used a Java Online Compiler via their mobile phones. The educator then divided the students into groups of 4–5 members based on the ZPD observed in the first meeting and with assistance from the Informatics teacher of the experimental class. Students were allowed to discuss while completing the worksheets. The educator supervised to ensure students remained calm and provided instructions if any student needed further explanation or assistance. At the end of the lesson, the educator and students discussed the completed worksheets. Students who had not finished the worksheets were asked to complete them at home.

The third meeting was held in Laboratory 1 at School. The topic covered in the third meeting was conditional statements, specifically if/else and switch statements. The educator started the lesson by greeting, taking attendance, and leading a prayer. Before continuing with the next material, the educator asked if there were any students who did not understand or needed further explanation regarding the previous lesson. Students who had not completed the previous worksheets were asked to submit their homework. After presenting the material, the educator distributed worksheets for the third meeting. Students worked in the same groups as before. The educator supervised and provided further instructions or explanations to students who needed them. At the end of the lesson, the educator and students discussed the completed worksheets. Students who had not finished the previous worksheets were asked to complete them at home.

The fourth meeting was conducted in Laboratory 1 at School. The topic covered was loops in Java, specifically for, while, and do-while loops. The educator began the lesson by greeting, taking attendance, and leading a prayer. Before continuing with the next material, the educator asked if there were students who did not understand or needed further explanation regarding the previous lesson. After presenting the material, the educator distributed worksheets for the fourth meeting. Students continued to work in the same groups as in previous meetings. The educator supervised and provided instructions to students who needed assistance. Students who had not completed the third meeting's worksheets were asked to finish them before proceeding with the fourth meeting's worksheets. At the end of the lesson, the educator and students discussed the completed worksheets. After the discussion, the educator distributed the post-test, which students completed independently. The post-test lasted 45 minutes and was conducted via Google Form.

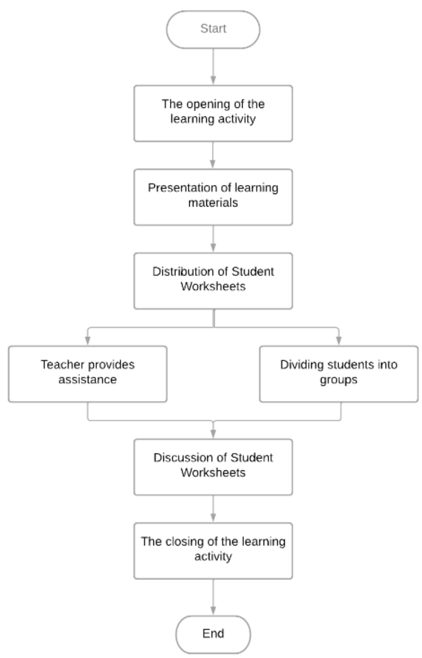

Figure 2. Experimental class learning activities diagram

The learning activities in the experimental class were conducted using the scaffolding learning method with detailed stages as outlined in Figure 2. Initially, the teacher began the session with a prayer and greeting, followed by a review of the previous learning material. The core activities involved the teacher presenting the learning material and dividing the class into several groups, each consisting of 4–5 students. Tasks were assigned to the students, and the teacher motivated them to engage in group discussions while working on their tasks, emphasizing that each student was independently responsible for their own work. The teacher provided guidance to students in need, ensuring that guidance did not directly solve the problems but encouraged students to find solutions independently. Finally, during the closing activities, the teacher and students jointly discussed the completed tasks, and some students were asked to review the activities carried out. The session concluded with the teacher leading a prayer and greeting.

Result and Discussion

Before the research commenced, the researcher administered a pre-test to assess the initial abilities of both the control and experimental classes. Additionally, the results of the pre-test allowed the researcher to determine whether the conditions of the two classes used in the study were comparable or not.

Result

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Table 4. Pre-test data statistic

Statistic	Control	Experiment
Count	36	36
Average	32,63	29.86
Median	35	30
Modes	35	35
Standard Deviation	7.69	9.37
Range	35	40
Minimum	15	10
Maximum	50	50

In the pre-test statistical data in Table 4, the control class obtained an average score of 32.78 with a minimum score of 15 and a maximum score of 50. The experimental class obtained an average score of 29.86 with a minimum score of 10 and a maximum score of 50.

At the end of the research period, the researcher administered a post-test to assess the difference in learning outcomes between the control and experimental classes. The control class underwent Java programming learning activities without any specific treatment, while the experimental class engaged in Java programming learning activities using the scaffolding learning method.

Table 5. Post-test data statistic

Statistic	Control	Experiment
Count	36	36
Average	74.72	78.58
Median	75	80
Modes	75	85
Standard Deviation	9.48	9.51
Range	45	40
Minimum	50	55
Maximum	95	95

The post-test statistical data in Table 5 indicates that the control class obtained an average score of 74.72, with a minimum score of 50 and a maximum score of 95. The experimental class obtained an average score of 79.58, with a minimum score of 50 and a maximum score of 95.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Kontrol	.155	36	.029	.947	36	.083
Eksperimen	.160	36	.021	.927	36	.020

Figure 3. Normality test result

Prior to examining research data against hypotheses, the data's normality and homogeneity are assessed first. In this research, normality and homogeneity tests are conducted using SPSS. Normality tests are conducted to analyze if the obtained data sets are normally distributed. In accordance with the results of the Kolmogorov-Smirnov normality test in Figure 3, the significance value of the control class post-test data was 0.29. Since the control class significance value is greater than 0.05, the post-test data for this class can therefore be considered to be normally distributed. For the experimental class post-test data, the significance value was 0.02. Since this value is less than 0.05, this data is considered to be not normally distributed. Therefore, the use of parametric tests would not be applicable. The experimental class's post-test data was marked by a negatively skewed distribution of -0.717, resulting in what is commonly known as a 'ceiling effect' whereby the majority of participants scored at the higher end of the scale.

The homogeneity test is conducted to determine whether the two sampled data sets are from populations with the same variance. Based on the results of the homogeneity test in Figure 4, the significance obtained is 0.904. Since the significance value of the homogeneity test is greater than 0.05, it can be concluded that the post-test data of the control and experimental classes have the same variance or are homogeneous.

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Based on Mean	.001	1	70	.970
Based on Median	.009	1	70	.924
Based on Median and with adjusted df	.009	1	69.907	.924
Based on trimmed mean	.015	1	70	.904

Figure 4. Homogeneity test result

Independent Samples Test

Levene's Test for Equality of Variances		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
.588	.446	-2.416	70	.018	-7.77778	3.21962	-14.19911	-1.35645
		-2.416	68.344	.018	-7.77778	3.21962	-14.20185	-1.35371

Figure 5. Hypothesis t-test results

Test Statistics[a]

	Hasil
Mann-Whitney U	435.000
Wilcoxon W	1101.000
Z	-2.433
Asymp. Sig. (2-tailed)	.015

a. Grouping Variable: Kelas

Figure 6. Hypothesis Mann-Whitney U test results

Since post-test data do not follow a normal distribution, a Mann-Whitney U test was performed and the result was Asymp. Sig (2-tailed) = 0.015. In addition, the gain score t-test produced a t-value of -2.416 with a significance of 0.018. These results are illustrated in Figures 5 and 6. Because both results are less than 0.05, this means that Ho is rejected and that the scaffolding method was effective.

Discussion

In Figure 7, three students from the control classes and nine from the experimental classes scored less than 20. Thirty students from the control classes and twenty-five from the experimental classes scored between 21 and 40. Three students from the control classes and two from the experimental classes scored between 41 and 60. In Figure 8, we see that one student from the control class and three students from the experimental class scored between 41 and 60. Twenty-seven students from the control class and 17 from the experimental class scored between 61 and 80. Eight students from the control classes and 16 from the experimental classes scored 81 and above.

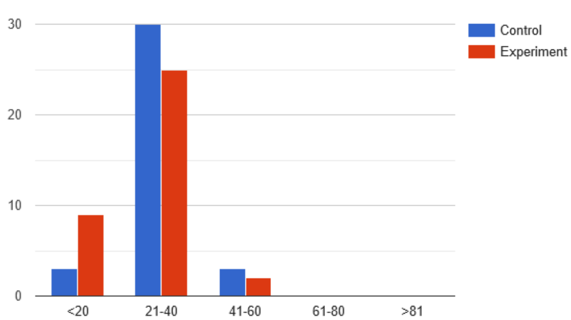

Figure 7. Pre-test data histogram

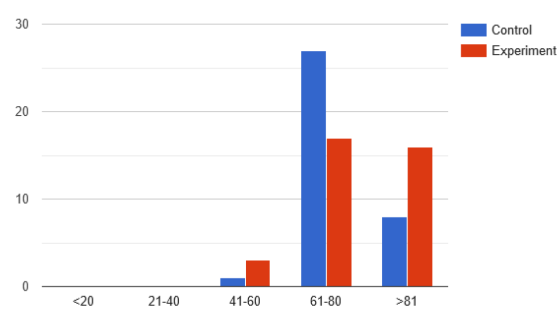

Figure 8. Post-test data histogram

The significant results from this study show that the application of the scaffolding method shifts student performance significantly to higher level of proficiency compared to conventional instruction. In the post-test distribution, (Figure

8), the scores of the experimental group were distributed higher than those of the control group and significantly, the number of students in the scaffolding class who scored 16 above 81 was twice that of the control class who scored 8. This pointed out a considerable positive change in the proficiency of students in advanced level programming. It means that scaffolding does more than help students just pass. It enables a major part of the class to attain a higher level of understanding the fundamental programming concepts using the Java programming language.

The experimental group showed the best result thanks to the "ceiling effect," demonstrated with negatively skewed distribution (Skewness -0.717). While traditional approaches left a lot of students (44.44 %) struggling to meet the Minimum Competency Standard (KKM), with the scaffolding approach, 83.33% of the students were able to reach the result. In this case, the success is due to the students advance through their Zone of Proximal Development (ZPD). The teacher's modelling of logic demonstrations and the provision of hints to correct logic errors likely steered clear of the beginner's typical frustration with basic programming concepts when using Java.

Additionally, the scaffolding treatment's peer tutoring and collaborative learning features encouraged active participation. By making students social knowledge constructors rather than passive recipients of information, they were able to actively negotiate knowledge, with the assistance of more advanced peers, to close the gaps for students with a lower initial ZPD. This way, students were able to work around the challenge of learning structured programming and object-oriented programming concepts at the same time.

The findings are consistent with Chairani (2015) who observed that scaffolding helps in minimising learning obstacles by connecting current knowledge with new forthcoming skills, and Sidin (2016) who validated the effectiveness of scaffolding in programming, in particular. Most importantly, the experimental group with the gain score of 49.72% (compared to 41.94% of the control group) demonstrates that more structured support is needed in order to attain the informatics components of the Merdeka Curriculum.

The study did confirm the interventions of scaffolding technique's positive impact but there are a few limitations that should be discussed. The first issue is that the study was sampled at one singular school over the course of the study with only 72 students which could limit the potential for these results to be used to inform a broader field of vocational education. The second issue is that the intervention was conducted across a very short time span of just four learning sessions. This time span is too short to make any conclusions about the students' retention of programming logic or the retention of any positive effects caused by the scaffolding method. The third issues is about the measuring tool that was a 20-question multiple choice quiz that the students were supposed to answer. Although the quiz does claim to be a valid and reliable tool to measure a student's understanding of the concepts of the variables, conditions and loops, it really does not measure a student's hands on coding ability or their ability to solve a problem with the coding language that is required to develop this software. There were several areas that were left unresolved in the study, solely due to the limited time span of the interventions, and these areas could be addressed in the future by using a wider variety of assessments and by utilizing a longer duration of study so that a better more thoroughly to be able to be developed.

Conclusion

Based on the results of the research and discussion, it can be concluded that the application of the scaffolding method has a significant positive effect on students' programming abilities at a State Vocational School. Statistical analysis using the Mann-Whitney U test on post-test scores yielded an Asymp. Sig (2-tailed) value of 0.015, while the gain score analysis showed a significance level of 0.018, both of which are below the 0.05 threshold. This indicates a significant difference in improvement between the groups, with the experimental class achieving a higher average gain of 49.72% compared to the control class's 41.94%.

Practically, the experimental class achieved a final average score of 79.58, outperforming the control class's average of 74.72. Furthermore, 30 students (83.33%) in the experimental class successfully reached the Minimum Competency Standard (75), whereas only 20 students (55.56%) in the control class achieved the same. Therefore, it is concluded that the scaffolding method is more effective than conventional instruction in enhancing students' beginning programming skills.

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