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Improving Students' Understanding and Learning Outcomes in Algorithms through Scratch-Based Interactive Learning Media

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ABSTRACT

This research aims to develop and evaluate the effectiveness of a learning medium based on the visual programming language Scratch in enhancing tenth-grade students' understanding and learning outcomes of algorithmic concepts at SMAN 32 Jakarta. The study is motivated by the low level of student engagement during the learning process, primarily attributed to monotonous conventional teaching methods, limited student autonomy in learning, and the lack of interactive and engaging instructional media. Notably, supporting infrastructure, such as laboratories and technological devices, is already in place. The study employed a Research and Development (R&D) approach using the ADDIE model, with experimental testing through a Pre-test Post-test, Control Group design. Research instruments included questionnaires and learning outcome tests, with data analyzed using mean difference tests. Based on validation from experts and student feedback, the Scratch-based media was deemed highly feasible. Experimental results revealed a significant improvement in the learning outcomes of the experimental group compared to the control group, with a gain score reaching 72.4% by the second session. These findings indicate that Scratch-based instructional media is both feasible and effective in improving students' comprehension and achievement in algorithmic material. Therefore, it is recommended as a strategic alternative for teaching informatics.

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1. INTRODUCTION

Education is an increase in the value of a person or group's civilization from a particular situation to a better situation, and the process is through research, discussion, or reflection on problems or symptoms of educational actions (Ornovetchii, 2023; Sriatun et al., 2024) . The purpose of its implementation is to prepare students thoroughly to give meaning to life and answer the challenges of life they experience (Schinkel et al., 2016) . As the core education process, learning must be carried out by positioning students as key actors (Emelyanova et al., 2024) .

Dynamic learning content tailored to how today's learners read, think, and learn, including integrated video and interactive media (Alias & Razak, 2025; PJ Singh & Gera, 2024) . In narrative videos, learners are empowered to engage with concepts and actively participate in learning. Programming skills are currently being developed for the implementation of informatics subjects; however, before understanding programming, it is beneficial to first grasp algorithms (Gonda et al., 2022; Papayannopoulos, 2023) . Algorithms are a fundamental foundation of computational thinking. In computational thinking, students are encouraged to develop critical, creative, and communicative thinking skills, as well as the ability to collaborate in solving problems (Palop et al., 2025) .

The results of observations and interviews at SMAN 32 Jakarta show that there are still many students who tend to be passive or less active in participating in learning, especially algorithm material due to monotonous learning, students are not interested and cannot solve problems through the tasks given so that it has an impact on learning outcomes, lack of ability to develop computational thinking of students, less independent in reading learning resource literature, there are still many students who are late in collecting assignments and students who tend to depend on educators. Most learning still relies on conventional methods, despite the existence of supporting facilities for the learning process, such as laboratories, computer devices, LCDs, sound systems, and internet networks. In addition, students often lack an explicit reference for learning resources when educators deliver learning materials, and are still dependent on educators. Therefore, interactive learning methods and integrated learning media are necessary as supplementary resources for student learning (Seifullina & Shokybayev, 2024) .

The difficulty that students face in understanding the algorithm material of informatics subjects, as researchers found in the results of observations and interviews at SMAN 32 Jakarta, is highly dependent on the students' taste and mastery. The problem is that some students still have not mastered the programming language or selected the right software/platform for expressing algorithms. Students also have limitations in thinking logically and systematically in compiling a good and clear algorithm flow, so they are less able to show a problem with a high level of difficulty being broken down so that it looks unclear (Cheah, 2020) . In addition, students only stop at the right results, and do not consider the time and memory drained by the algorithm used, because the basis for creating an algorithm is the efficiency of time, memory, and the correct output (Velázquez-iturbide, 2021) .

Referring to the problem of boredom and saturation during learning, innovation is necessary to enhance learning achievement by providing adequate and varied learning media. Learning media is divided into two types: Information Communication Technology (ICT)-based learning media and Non-ICT-based learning media (Emelyanova et al., 2024; Gupta et al., 2021) . One of the media products that can be used based on ICT is the visual programming language Scratch (Alfi Rosydiana et al., 2023; Liao, 2023; Pinto & Escudeiro, 2014) . The Lifelong Kindergarten research group at MIT Media Lab developed the Scratch visual programming language. The Scratch visual programming language can be used to create interactive stories, interactive games, and animations, and can be shared with others via the internet (Stahlbauer et al., 2020) .

The results of a study (Wu et al., 2023) show that computational thinking can be implemented through visual programming languages to simplify learning, even though algorithm material has not been the main focus. Currently, programming algorithm material is being developed for Informatics subjects in Indonesian high schools. This research aims to create Scratch-based learning media in the form of stimulus videos to improve learning outcomes at SMAN 32 Jakarta and to measure the feasibility and effectiveness of Scratch-based learning content. Theoretically, the benefits include enriching knowledge and serving as a reference for further research. Practically, it provides educators with flexibility in time and place and increases learning interactivity.

2. METHOD

Research and Development is an approach used by researchers in developing algorithm learning media based on the visual programming language Scratch in informatics subjects. The research design uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) (Lee & Owens, 2004) .

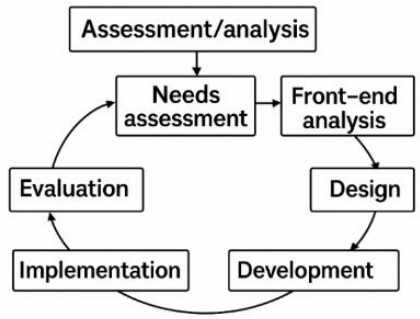

Figure 1ADDIE development method

The development of media using ADDIE in this study is intended to support algorithm learning based on the visual programming language Scratch. The stages of ADDIE development are Analysis with needs assessment and front-end analysis, Design, Development, Implementation, and Evaluation (Lee & Owens, 2004) .

This research is a type of experimental study, specifically designed to assess the impact of a treatment on the matter being investigated. Experimental research is carried out by comparing the experimental group that was given treatment with the comparison group (control) that was not given treatment (Cariveau & Fetzner, 2022; K. Singh et al., 2022) . The research design employed is the Pretest-Posttest Control Group Design. In this design, the sample is divided into two groups: the experimental group and the control group. The following table shows this research design.

Table 1. Research Design: Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	Y_1	X_1	Y_2
Control	Y_3	X_2	Y_4

Information:

Y1 : Experimental class learning results before being given treatment
Y2 : Learning outcomes of the experimental class after being given treatment
Y3 : Learning outcomes of the control class before being given treatment
Y4 : Learning outcomes of the control class after being given treatment
X1 : Treatment with learning media algorithms based on the visual programming language Scratch
X2 : Treatment with conventional learning

First, the experimental and control groups were administered a pretest before receiving treatment, and then both groups received a posttest after treatment. The pretest aims to determine students' understanding of the material or treatment that will be given (Kliegl & Bäuml, 2025; Parker & Kao, 2022) . The posttest is conducted to assess the effect of the treatment that has been given. The results can show the effectiveness of learning media algorithms based on the visual programming language Scratch and conventional methods in improving learning outcomes.

The variables for this study are divided into independent variables (free variables) and dependent variables (bound variables). The independent variables affecting this study's dependent variables are the algorithm learning media based on the visual programming language Scratch. The dependent variables influenced by the independent variables in this study are students' learning outcomes in the Algorithm material of Class X at SMAN 32 Jakarta.

This research instrument is in the form of a student learning outcome test. This test instrument can be used to see basic abilities, achievements, or work results. The test guidelines in this study include both pretests and posttests. This instrument will then collect student scores. The test will be administered to both the treatment class (the experimental group) and the class without treatment (the control group) at the beginning and end of the learning period. This test instrument consists of multiple-choice questions, with 20 questions for each experimental class and control class at each meeting. In this study, two meetings were held, with each meeting including a pretest and a posttest.

This instrument trial was conducted to see whether the questions or issues met the valid and reliable requirements for use as an instrument (Sugiyono, 2018) . Therefore, instrument testing used validity and reliability tests.

Table 2. Reliability Level Table Based on Alpha Value

Alpha (α)	Reliability Level
0.00 – 0.20	Less reliable
0.21 – 0.40	Somewhat reliable
0.41 – 0.60	Quite reliable
0.61 – 0.80	Reliable
0.81 – 1.00	Very reliable

Source: (Sugiyono, 2018)

The analysis technique was applied to the research data to answer the question of how practical and feasible the visual programming language-based learning media, Scratch, is in improving student learning outcomes in the Algorithm material for class X Phase E of SMAN 32 Jakarta in the 2023/2024 academic year. This study's analysis technique used descriptive statistics and classical assumption tests (normality and

homogeneity tests). The research hypothesis was tested using parametric analysis. Hypothesis testing in this study used SPSS version 25.0 for Windows with a significance level of 0.05.

The subjects of this study were students in Class X Phase E of SMAN 32 South Jakarta in Indonesia for the 2023/2024 academic year. In the media usage test , 15 students were randomly selected from class The research data were obtained from the pre-test and post-test results of the informatics subject, specifically the learning outcomes related to algorithm learning achievements. The experimental data analysis technique used the average difference test. In this study, a team of experts conducted a validation test to see the feasibility of the learning media from the material and media aspects. Furthermore, the learning media were delivered to students to determine their responses to the learning media resulting from the development.

This research data analysis used quantitative descriptive analysis techniques. Researchers used this technique to process data obtained through expert validation questionnaires and student assessment questionnaires. Data analysis involved converting questionnaire scores, which originated from qualitative data, into quantitative data using a Likert scale.

Table 3. Eligibility Category Table

Formula	Average Score	Category
$\bar{X} > \bar{X}_i + 1.8Sb_i$	$\bar{X} > 3.40$	Very Feasible
$\bar{X}_i + 0.6Sb_i < \bar{X} \leq \bar{X}_i + 1.8Sb_i$	$2.80 < \bar{X} \leq 3.40$	Feasible
$\bar{X}_i - 0.6Sb_i < \bar{X} \leq \bar{X}_i + 0.6Sb_i$	$1.60 < \bar{X} \leq 2.80$	Not feasible
$\bar{X} \leq \bar{X}_i - 1.8Sb_i$	$\bar{X} < 1.60$	Totally not Feasible

Information:
Highest score = 4
Lowest score = 1
$\bar{X}_i$ = ideal average = $^1/_2$ (highest score + lowest score)
Sb_i = ideal standard deviation = $^1/_6$ (highest score - lowest score)

Table 4. Validation Results Table by Subject Matter Expert

No	Statement	Category	Score
1	The media presented is relevant to the material studied by students according to the curriculum.	S	3
2	Goals and benefits are clearly communicated	S	3
3	The content of the material has correct and precise concepts.	S	3
4	The content of the material is in accordance with the flow of learning objectives	S	3
5	The content of the material is in accordance with learning outcomes	SS	4
6	The content of the material is in accordance with the learning objectives	SS	4
7	The media presented is relevant to the main material being studied by students.	S	3
8	The media is in accordance with the current curriculum.	S	3
9	Media is easy for students to understand	SS	4
10	Students do not get bored using media	SS	4
11	The material content includes illustrations and example questions.	SS	4
12	Media encourages students to try to get the correct answer	S	3
	Total Score		41
	Percentage Score		85.4%
	Average Score		3.42
	Average Score Interval		> 3.40
	Category		Very Feasible

The normality test is a statistical test to determine whether the data follows a normal distribution, which is an important requirement in parametric analysis. This study used the Kolmogorov-Smirnov test with the help of SPSS 25.0. If the significance value (Sig.) > 0.05, the data is considered normal; if Sig. < 0.05, the data is not normal. In this study, the pretest data of meeting 1 of the experimental class, as well as the pretest of meeting 1, posttest of meeting 1, and pretest of meeting 2 of the control class had a significance value (Sig.) > 0.05 so that they were normally distributed. Meanwhile, the posttest data of meeting 1, pretest and

posttest of meeting 2 of the experimental class, and posttest of meeting 2 of the control class had Sig. < 0.05 so they were not normally distributed.

To compare two different sample groups, if the data is normal, the parametric independent sample t-test is used, if it is not normal, the nonparametric Mann Whitney test is used. To compare two paired sample groups, if the data is normal, the paired sample t-test is used, if it is not normal, the nonparametric Wilcoxon Signed Rank Test is used. If the data is normally distributed, if the two groups are different, then use the Independent Sample t-test but if the two groups are paired, then use the Paired Sample t-test. If the data is not normally distributed, if the two groups are different, then use the Mann–Whitney but if the two groups are paired, then use the Wilcoxon Signed Rank Test.

The homogeneity test is a statistical test to determine whether a variance (diversity) of data from two or more groups is homogeneous (the same) or heterogeneous (not the same). The decision-making guideline in the homogeneity test is if the significance value (*Sig.*) *Based on Mean* > 0.05 then the data variance is homogeneous, conversely, the significance value (*Sig.*) *Based on Mean* <0.05 then the data variance is not homogeneous. The results of the homogeneity test use the *Levene test* . The table above shows that the variance of *the pretest* and *posttest* of meetings 1 and 2 in the experimental and control classes obtained a significance value *(Sig. Based on Mean)* > 0.05, so it is stated that the data in this study have a homogeneous variance. In addition, the researcher conducted a validation test of the instrument (questions) before being used for collecting research data in the experimental and control classes. The instrument validation test was carried out by competent experts in the relevant fields, namely lecturers from the PTEI Department, FT UNY and informatics subject educators at SMAN 32 Jakarta. In addition, the questions were tested on 30 class X-2 students, where out of 25 questions, there were 5 questions that were failed or invalid. The failed questions based on the results of the validity test with the Pearson correlation formula obtained a calculated r value smaller than the r table at a significance level of 0.05 with a sample size (n) of 30, namely 0.361. From the reliability calculation, the Cronbach's Alpha value of 0.841 was also obtained, which was greater than 0.60, meaning the instrument was reliable with very high criteria. After the instrument validation test was conducted and 20 valid questions were obtained, these questions were used to collect research data in the experimental and control classes before the treatment (pretest) was carried out. Then, the treatment was given, where the experimental class used learning media based on the visual programming language Scratch, while the control class did not use learning media based on the visual programming language Scratch or only used the lecture method. After both classes were given the treatment, a posttest was given to both classes. This was done to determine the students' understanding of the material after the treatment.

3. RESULTS AND DISCUSSION

3.1. Results

Based on the empirical data derived from the analysis of pre-test and post-test assessments related to educational outcomes in informatics subjects, the academic accomplishments in algorithms were examined. The instructional media, which is based on the visual programming language Scratch, can be innovatively designed to enhance the educational outcomes of students in Phase E of Class X at SMAN 32 Jakarta. This instructional media is presented in the form of a video stimulus that addresses algorithmic concepts, enabling a comparative analysis of post-test educational outcomes between the experimental and control cohorts. A statistically significant disparity was identified in the post-test educational outcomes of both the experimental and control groups during the first and second meetings.

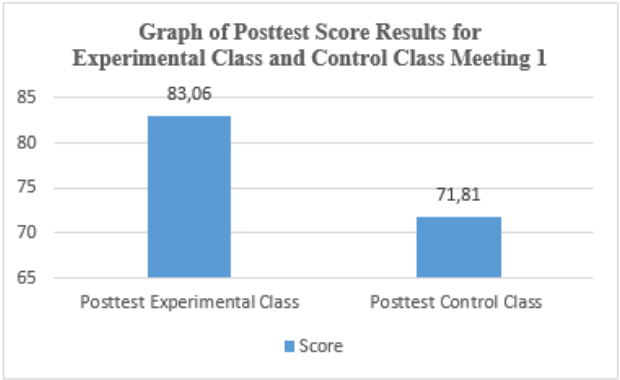

Figure 1Posttest Score Results for Experimental Class and Control Class Meeting 1

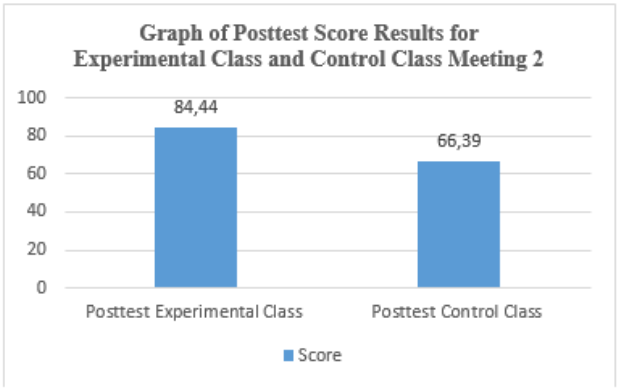

Figure 2. Posttest Score Results for Experimental Class and Control Class Meeting 2

The analysis of pre-test and post-test results indicates a pronounced positive impact of the Scratch-based visual programming language learning media on student learning outcomes in algorithms. A significant disparity in post-test scores was evident between the experimental and control groups across both instructional meetings, with the learning media for the experimental group delivered as a video stimulus of algorithm material.

At the first meeting, data analysis revealed that the experimental class, which utilized the Scratch-based media, achieved an average post-test score of 83.06, significantly surpassing the control class's average of 71.81. The statistical significance of this difference ($p=0.009$, which is less than the significance level of 0.05) substantiates that the enhanced performance in the experimental group was attributable to the intervention rather than chance. This positive trajectory was maintained and amplified during the second meeting. The experimental class's average post-test score rose to 84.44, markedly exceeding the control class's average of 66.39. The Mann-Whitney U test, employed for analyzing the second meeting's data, further corroborated this highly significant difference ($p=0.000$). These findings consistently affirm the superiority of Scratch-based learning media in elevating student learning outcomes relative to the conventional lecture methodologies implemented in the control group. Notably, the improved learning outcomes of Grade X Phase E students at SMAN 32 Jakarta, who engaged with the Scratch media, also surpassed the established Learning Objective Completion Criteria (KKTP).

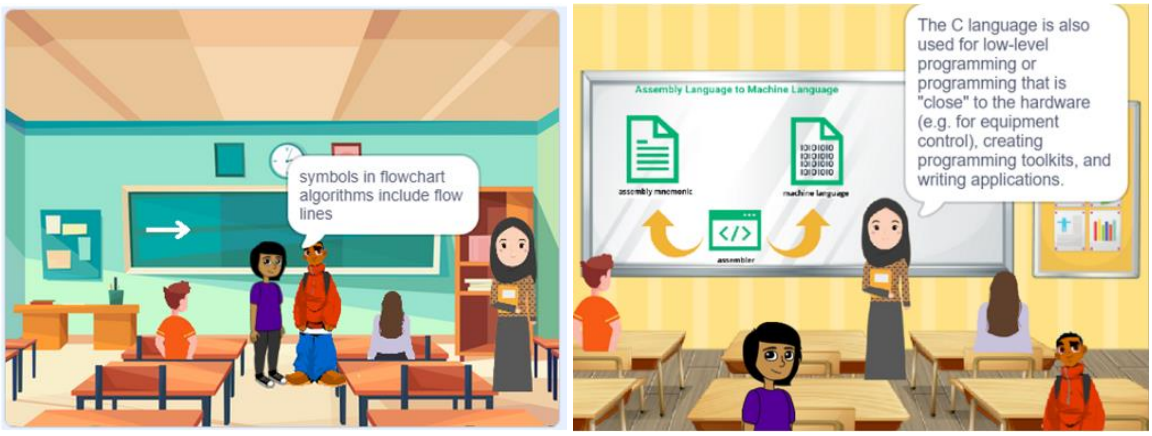

Figure 2The learning media scratch

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Figure 3Students using Scratch learning media and presenting algorithm results

The feasibility test results indicate that learning media based on the visual programming language Scratch is highly suitable for use as educational tools. The results are as follows:

a. The average validation score of the material by validator 1 was 3.42 (very feasible category), validator 2 was 3.42 (very feasible category), and validator 3 was 4.00 (very feasible category).
b. The average media validation score by validator 1 was 2.83 (feasible category), validator 2 was 3.42 (very feasible category), and validator 3 was 3.92 (very feasible category).
c. The average score of the media usage test by students was 3.30 (adequate category).

The effectiveness of the Scratch learning media was further delineated through gain score analysis. The gain score was 60.1% at the first meeting, increasing to 72.4% by the second meeting. These figures denote a moderate to practical impact on enhancing student learning outcomes. This implies that Scratch media is operationally feasible and make a tangible, positive contribution to students' comprehension and mastery of algorithmic concepts. The confluence of significantly superior learning outcomes, robust feasibility assessments, and commendable effectiveness levels provides compelling evidence that Scratch-based interactive media represents a strategic and valuable pedagogical alternative in informatics education, particularly for algorithmic instruction.

This study contributes empirical evidence that reinforces the utility of Scratch in informatics education. The observed increase in learning outcomes and student interest when using Scratch media, attributed to its interactive and visual nature, allowing for easier comprehension through animated videos, is consistent with the foundational goals of such platforms (Cárdenas-Cobo et al., 2021) . Scratch was developed to make programming and computational thinking more accessible and engaging for learners (Kuz, 2023) (Núñez-Naranjo et al., 2023) . Therefore, while a direct comparative analysis of specific result metrics with other named studies is not available within this text, the successful application and positive results reported herein support the broader body of educational research advocating for the use of interactive, visual tools like Scratch to improve learning in complex subjects such as algorithms (Maraza-Quispe et al., 2021) .

Furthermore, this research extends the understanding of Scratch's utility by providing concrete metrics of its effectiveness, such as a gain value reaching 72.4% at the second meeting, and thorough feasibility assessments conducted within the specific educational environment of a public senior high school in Jakarta (SMAN 32 Jakarta). Research exploring inclusive pedagogy in teaching coding and discussing program analysis for learners' programs highlights Scratch's extensive capabilities and pedagogical reach; in this context, the present study offers localized, empirical validation of its application for enhancing algorithm instruction. These specific findings, including the significant increase in learning outcomes for the experimental class, provide practical insights for educators considering the adoption of Scratch, demonstrating its potential to make learning more engaging and yield measurable improvements in understanding complex subjects like algorithms among secondary school students.

3.2. Discussion

3.2.1. Enhanced Conceptual Understanding through Visualization

One of the notable findings from this study is the improved conceptual understanding of algorithmic processes among students who used Scratch-based visual programming media. Traditional instruction in algorithms often presents abstract concepts through static text or symbolic code, which can be difficult for learners to understand, especially at the introductory level (Mtaho & Mselle, 2024) . In contrast, Scratch allows these concepts to be visualized in dynamic and interactive ways (Santos et al., 2024) . Students can observe how an algorithm operates through animations and graphical outputs, making it easier to follow logical sequences and identify errors in real-time. This visual and step-by-step representation supports learners in building mental models of how algorithms work (Santos et al., 2024) . The significantly higher post-test scores in the experimental group compared to the control group provide strong evidence that visualization through Scratch enhances comprehension. By transforming abstract procedures into tangible actions, the media fosters a deeper understanding of the underlying structure of algorithms, making learning more intuitive and meaningful for students.

3.2.2. Inclusivity for Diverse Learning Styles

The implementation of Scratch in algorithm instruction proved effective in accommodating a wide range of student learning styles (Ibrohim et al., 2023) . While conventional teaching methods often rely on verbal explanations and written materials, Scratch offers a visual and interactive alternative that aligns well with students who learn best through visual-spatial and hands-on experiences. The drag-and-drop interface, colorful block coding, and immediate visual feedback allow students to actively engage with the content, constructing and modifying their own programs. This interactivity encourages exploration and experimentation, helping students better internalize algorithmic logic (Ergash O'G'Li et al., 2024) . The overall improvement in student performance suggests that the media not only benefited a particular group of learners but also provided equitable learning opportunities across the classroom. By addressing different cognitive preferences, Scratch supports a more inclusive learning environment where all students, regardless of their preferred learning mode, can access and succeed in mastering algorithmic concepts(Vasconcelos et al., 2023) .

3.2.3. Feasibility and Practical Application in Educational Contexts

This study demonstrates that Scratch-based media can be effectively implemented within the standard learning environment of secondary schools. The use of Scratch programming activities was smoothly integrated into regular classroom sessions without disrupting the existing instructional flow. Students were able to operate the media independently after brief instruction, indicating that the tool is user-friendly and well-suited for student-centered learning. The increase in gain scores from the first to the second meeting, reaching 72.4%, reflects the practicality and sustained impact of the media over time. These results suggest that integrating Scratch not only enhances academic performance but also supports long-term engagement and learning progression. Its application does not require specialized infrastructure or prior coding experience, making it a viable and scalable solution for schools seeking to strengthen their informatics education with limited resources (Frantskevich & Prostak, 2023) . Thus, Scratch emerges as a practical instructional tool that aligns well with the realities and constraints of formal classroom settings.

Several previous studies have shown the effectiveness of using Scratch in learning. In the study by Permana, Sufa & Hapsari, the Scratch-based learning module was assessed as very feasible by media experts (84%), material experts (85%), and received positive responses from students (82%), making it suitable for use in schools and independent learning. In the study by Aulia, Zetriuslita, Amelia & Qudsi, the use of Scratch in trigonometry material increased students' interest in learning by an average of 77.6% (high category). The study by Hardiansyah, Armin & Rahmadi, the implementation of games using Scratch increased learning outcomes (from 25.7% pre-cycle to 94.3% in cycle 2) and students' learning motivation (from 40.3% to 83.9%). Overall, these studies prove that Scratch is effective in increasing media feasibility, student interest and learning outcomes.

4. CONCLUSION

The use of visual programming language-based instructional media, specifically Scratch, for the informatics subject in the sub-topic of algorithms, has been deemed appropriate for educational implementation. A statistically significant difference was found between the pretest and posttest results from sessions 1 and 2 in the experimental group, indicating that integrating Scratch as a visual programming tool is effective in enhancing students' learning outcomes. In contrast, although the control group also exhibited significant differences between their pretest and posttest scores, the improvement was less substantial. This suggests that the traditional lecture method is less effective in fostering meaningful learning gains in the same subject area. These findings underscore the need for educators to adopt innovative teaching tools that can better support student learning, with Scratch being a viable option.

The results further demonstrate a notable difference in the effectiveness between the use of visual programming-based media (Scratch) and the lecture method in improving the learning outcomes of tenth-grade students at SMAN 32 Jakarta in the informatics subject, specifically in the algorithm sub-topic. Instructional media that utilize visual programming languages, such as Scratch, are more effective in enhancing student performance compared to conventional methods. The higher achievement levels observed in the experimental group were attributed to students' increased engagement and better understanding of the material when it was presented through animated and interactive video content within the Scratch environment. As a result, this innovation in educational content delivery through visual programming language-based media, such as Scratch, has been proven to be an effective means of improving student learning outcomes in informatics at SMAN 32 Jakarta.

This study has limitations such as the short data collection time, insufficient sample size, and changes in the research environment that affected the data relevance. Further research is recommended to develop Scratch-based learning media for algorithms and other curriculum-based materials, with more varied formats, to improve the quality of learning at SMAN 32 Jakarta.

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