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Enhancing Computational Learning through Visual Programming Media: An Empirical Study of Academic Achievement

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Abstract

The integration of computational thinking into formal education curricula has become essential as information and communication technology continues to transform educational paradigms. This study addresses a significant challenge in computer science education, where 58% of junior high school students fail to achieve minimum learning standards in programming subjects. Objective this study to develop and evaluate the feasibility and effectiveness of visual programming learning media using Scratch 3.0 to enhance academic achievement in computer science education among seventh-grade students. This research employed a research and development approach using a 4-D model (Define, Design, Develop, Dissemination) conducted at Dr. Wahidin Sudirohusodo Junior High School over two months. The study involved comprehensive validation by three expert validators and implementation across three phases: a small group (n=5), a medium group (n=15), and field testing (n=30). The data collected included expert validation questionnaires, pre- and posttest assessments, and perception surveys, which were analyzed via descriptive statistics and t tests. Expert validation demonstrated high feasibility, with material validation scoring of 87%, media validation scoring of 83.5%, and instructional design validation scoring of 84.5%, all of which were categorized as "Very Good." The effectiveness evaluation revealed an overall effectiveness of 92.73% in the "very good" category. Statistical analysis revealed significant differences between the experimental and control groups (t-stat = 5.06, $p < 0.001$), with the experimental group achieving a mean score of 77.00 compared with 70.60 for the control group. Scratch 3.0-based visual programming learning media is feasible and effective for enhancing computer science learning outcomes, demonstrating superior performance compared with conventional teaching methods in junior high school education.

Keywords: Visual programming, educational technology, computational thinking, computer science education, learning media, scratch programming, academic achievement.

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1. Introduction

The information and communication technology revolution has fundamentally changed the educational paradigm, creating an urgent need to integrate computational thinking skills into the formal education curriculum (Haleem et al., 2022). Informatics learning in junior high schools plays a strategic role in preparing students for the digital era by providing a foundation of knowledge about hardware, software, information security, and digital ethics (Elegbeleye & Isong, 2025; Kalelioğlu, 2015; Noone & Mooney, 2018; Wang et al., 2024). The implementation of the Merdeka curriculum in informatics learning represents a progressive step to prepare the younger generation for future technological challenges, where programming skills not only open up career opportunities in the technology sector but also significantly improve learners' analytical and problem-solving abilities (Adnyana et al., 2023).

Park and Shin (2019) emphasized that digital literacy is an essential skill for identifying and avoiding the spread of false information and protecting personal privacy. In the informatics curriculum, cybersecurity learning provides a comprehensive understanding of digital risks, such as malware, phishing, and ransomware attacks, and mitigation strategies through effective security practices (Saritepeci et al., 2024). However, the implementation of technology in education faces multidimensional challenges that affect the effectiveness of learning programming (Cárdenas-Cobo et

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al., 2021; Noone & Mooney, 2018; Sandoval-Reyes et al., 2011).

Empirical data show an alarming phenomenon in the achievement of student learning outcomes, with 165 out of 285 students (58%) not achieving the minimum grade set (Kalelioğlu, 2015; Piedade & Dorotea, 2022). This indicates a lack of understanding of fundamental concepts or difficulty in applying theoretical knowledge in a practical context. Wang et al. (2024) reported that computer-based learning media act as catalysts for improving learners' learning outcomes by facilitating a more effective teaching process through the customization of diverse learning styles and preferences. Elegbeleye and Isong (2025) added that educational media serves as a bridge of interaction between teachers and students, creating a more engaging and efficient learning experience by simplifying complex concepts.

The complexity of traditional programming languages and the lack of understanding of basic concepts often lead to frustration and disinterest among novice learners. Cárdenas-Cobo et al. (2021) reported that a major challenge in learning introductory programming is learners' difficulty in understanding abstract concepts such as algorithms, program flow control, and programming logic. These concepts require pedagogical approaches that can concretize abstractions through visualization and hands-on interactions (Moreno, 2005).

Scratch, developed by the lifelong kindergarten group at MIT, has proven effective as a project-based programming learning platform with more than seven million registered users worldwide. Resnick (2017) argued that Scratch promotes creativity and collaboration among learners through an interactive and game-based learning approach. Pérez-Jorge and Martínez-Murciano (2022) reinforced these findings by stating that Scratch plays a fundamental role in teaching computational thinking and programming logic to learners. Zaranis et al. (2016) conducted a comprehensive evaluation and reported that the scratch-based learning approach significantly improved learners' programming skills and computational thinking, including increased motivation and self-efficacy in learning programming concepts. Sweller et al. (2019) explained that the use of visual and interactive media helps learners understand abstract concepts by providing concrete representations and simulations, thus making complex ideas more accessible to learners. Assulamy et al. (2023) reported that Scratch 3.0 offers the advantage of being a visual programming platform with an intuitive graphical interface, allowing users to create interactive projects without the need for prior textual programming knowledge.

An analysis of the literature reveals significant research gaps. Empirical studies that specifically test the effectiveness of Scratch 3.0 in improving the learning outcomes of seventh-grade junior high school students are still limited, especially in the context of Indonesian education. Previous studies have focused more on the technical aspects of using Scratch as a learning tool without examining its effect on improving learners' competencies in the cognitive, affective, and psychomotor domains. Piedade and Dorotea (2022) noted variations in informatics teachers' perceptions of the effectiveness and relevance of Scratch 3.0, which affected the level of adoption and quality of technology implementation in the classroom. On the basis of the problems and potential above, it is important to develop effective learning media to support the need for computational skills in various industries. The main objective of this research is to develop a learning media for programming using Scratch 3.0 that is feasible and effective in improving the learning outcomes of informatics subjects at Dr. Wahidin Sudirohusodo Junior High School Grade seven. This research aims to provide an alternative learning medium that is interesting and interactive to improve students' programming learning outcomes, as well as support the creation of an inclusive and innovative learning environment in preparing the younger generation for the Industrial Revolution 5.0.

2. Materials and Methods

2.1 Research design and setting

This study used a research and development approach with the 4-D model developed by Thiagarajan and Semmel (Haryadi et al., 2021). This model was chosen because it provides a systematic process for producing valid, effective, and applicable learning products through four stages: define, design, develop, and disseminate. The research was conducted at Dr. Wahidin Sudirohusodo Junior High School for two months, with the selection of locations on the basis that the school had not used digital application-based programming learning media. The define stage involves needs analysis through observation, interviews with teachers and learners, and analysis of curriculum documents to identify specific difficulties in understanding visual programming concepts. The design stage focuses on determining the learning media via Scratch 3.0 by preparing a media framework that includes structure, flow, and features divided into several learning modules. The development stage is carried out by creating learning media, validation by material experts, learning design experts, and media experts, followed by small- and medium-sized group trials. The Disseminate stage involves implementing media in a wider group with data collection on learner outcomes.

2.2 Population, sampling, and participant criteria

The study population included all 7th-grade students of Dr. Wahidin Sudirohusodo Junior High School who took informatics as their subject. The sampling technique used purposive sampling by considering the ability of daily test results (Adnyana, 2021). The sample was divided into a small group of five students for the initial trial, a medium group of 15 students for the limited trial, and a large group of 30 students for the field test. The inclusion criteria were as follows: Grade 7 learners who were actively enrolled in informatics according to the Merdeka curriculum, had access to digital devices, and were willing to participate in all research activities. The exclusion criteria included students who were absent from the pretest or posttest, experienced physical limitations that hindered the use of digital media, or did not complete the specified learning activities.

2.3 Research instruments and data collection

The research instrument consisted of a material expert evaluation questionnaire to assess the quality of the informatics learning material, a learning design expert evaluation questionnaire to assess the quality of the implemented design, a media expert evaluation questionnaire to assess the technical and aesthetic aspects, and a teacher and learner perception questionnaire. The instrument uses a Likert scale ranging from 1-5 and is very unfit to very fit the criteria. The programming ability test instrument in the form of multiple choices was validated by material experts through content validation, difficulty testing, differentiation testing, and error analysis. The test grid includes five basic competencies with 40 questions that measure the understanding of basic programming concepts, application of Scratch 3.0, simple program creation, error analysis, and presentation of work. Observation instruments were used to observe the students' learning activities, while interviews were conducted with eight informatics teachers to determine the needs of the learning media. The data collected included qualitative data in the form of comments and suggestions from expert validators, the results of interviews with teachers, and observations of learner activities. The quantitative data included media feasibility assessment scores, pretest and posttest results of programming skills, and perception data on the use of learning media.

2.4 Data analysis

A media feasibility analysis was conducted via qualitative and quantitative approaches (Sukmawati et al., 2024). Qualitative data were analyzed descriptively for media improvement, whereas quantitative data were converted to percentages via the formula $P = (\sum x/\sum xi) \times 100$ and categorized on the basis of feasibility criteria with ranges of 85-100% very feasible, 70-84% feasible, 55-69% quite feasible, 40-54% not feasible, and 0-39% very infeasible. The effectiveness analysis began with a prerequisite test, including a normality test using the Liliefors test and a homogeneity test using the F = large variance/small variance formula. After the assumptions were met, a t test was conducted to compare the learning outcomes between the experimental and control groups. Media effectiveness was measured via the normalized N-Gain formula, which is 71–100% highly effective, 31–70% effective, and 1–30% moderately effective. The effectiveness was compared by calculating the N-gain ratio of the two groups, where a value > 1 indicates that the learning media is more effective than conventional learning is.

3. Results and Discussion

3.1 Learning media feasibility validation

The validation process for the feasibility of learning media programming via Scratch 3.0 was carried out through a comprehensive evaluation by three expert validators in relevant fields. Material expert validation was conducted by Prof. Drs. Sriadhi, S.T., M.Pd., M.Kom., and Ph.D. from Medan State University assessed the feasibility aspects of content, language, and presentation through two stages of validation. In the first stage, the content and language feasibility aspects each scored 18 out of 20 (90%), whereas the presentation aspect scored 17 out of 20 (85%). After revision on the basis of the validators' feedback, the second stage improved, with the content and language eligibility aspects reaching scores of 19 out of 20 (95%) and the presentation aspect increasing to 18 out of 20 (90%).

Learning media expert validation was conducted by Dr. Ir. Agus Junaidi, S.T., and M.T. focused on aspects of material suitability from a technical media perspective. The validation results showed an increase from the first stage, with a score of 18 out of 20 (90%), to a score of 19 out of 20 (95%) in the second stage. The learning design expert validation was conducted by Prof. Dr. R.K. Mursid, S.T., M.Pd. who assessed the accuracy of the learning design.

The validation results revealed an increase from 18 out of 20 (90%) in the first stage to 19 out of 20 (95%) in the second stage. The summarized validation results show that the learning media reached a high level of feasibility, with an average material validation score of 4.35 (87%), a median validation score of 4.15 (83.5%), and a learning design validation score of 4.2 (84.5%). All aspects of validation fell into the "very good" category on the basis of the eligibility criteria set (Table 1).

Table 1. Expert validation results

No	Validation	Phase I		Phase II		Mean	P%	Criteria
		ATA	P%	ATA	P%			
1.	Material Validation	4	80%	4,7	94%	4,35	87%	Very good
2.	Media Validation	3,8	76%	4,5	91%	4,15	83,5%	Very good
3.	Learning design validation	3,8	87,5%	4,6	97,5%	4,2	84,5%	Very good

Remarks: ATA, average total assessment; P%, percentage.

Fig. 1. Learning media interface

3.2 Product trial results

The small group trial involved five randomly selected learners to provide initial feedback on the learning media. The evaluation results on Table 2 revealed that the learning media received a very positive response, with an average overall score of 89.41% in the "very good" category. The content feasibility aspect was the strongest, with an average score of 91.83%, where conformity with the curriculum reached the highest score of 96%. The presentation aspect obtained an average score of 89.67%, the linguistic aspect reached 92%, and the graphical aspect scored 90%. The medium group trial with 15 learners yielded consistent positive results, with the average overall score reaching 90.04% in the "Very Good" category. In terms of suitability to the curriculum, the highest score was 92%, the quality of material presentation reached 96%, and logical presentation received a score of 96%. The graphical aspect reached 93.33%, indicating consistently good visual quality. The field trial with 30 learners as a full-scale implementation resulted in an average overall score of 88.55% in the "Very Good" category. The clarity of the learning objectives obtained the highest score of 90%, followed by the correctness of the concept, with a score of 89.33%. The quality of the introduction was 89.60%, the use of language was 89.60%, and the use of visual images was 89.60%.

3.3 Effectiveness of learning media

The evaluation of the effectiveness of the learning media yielded impressive results, with the overall percentage of subvariables reaching 92.73% in the "Very Good" category. An increase in learner response to questions and activity in tasks reached 100%, learner motivation and interest in learning media reached 100%, and understanding of

programming concepts taught through learning media reached 100%. The learning outcomes aspect showed that the ability to develop reading skills and understand visual information reached 100%, the media's ability to motivate learners' learning reached 100%, the understanding of special programming in the field of informatics reached 100%, and the ability to remember information taught through learning media reached 100%.

Table 2. Comparison of phased trial results

Assessment Aspect	Group Small (%)	Medium Group (%)	Field Test (%)
Content eligibility	91.83	90.00	89.07
Presentation	89.67	89.33	88.53
Linguistics	92.00	91.33	89.07
Graphics	90.00	93.33	88.40
Average	89.41	90.04	88.55

The normality test via the Liliefors test revealed that the pretest data were normally distributed, with L_hitung = 0.1698 < L_table = 0.1766, but the posttest data were not normally distributed, with L_hitung = 0.5148 > L_table = 0.1766. The homogeneity test revealed that both groups had homogeneous variances, with F_hitung = 0.101 < F_tabel = 0.69 at a significance level of 5%. The t test results revealed significant differences between the experimental and control groups, with t_hitung = 1.192 > t_table = 0.68; therefore, the alternative hypothesis was accepted. The experimental group using Scratch 3.0 learning media obtained an average score of 77.00 with a standard deviation of 8.55, whereas the control group using conventional learning obtained an average score of 70.60 with a standard deviation of 8.49.

The gain score analysis (Table 3) revealed that the experimental group obtained an average gain of 14.8, with a variance of 104.92, whereas the control group obtained an average gain of 4.77, with a variance of 12.87. The t test with the assumption of unequal variances resulted in t-statistics = 5.06, with p values = 0.000006 (one-tail) and 0.000012 (two-tail), indicating a significant difference. The effectiveness of programming learning media via Scratch 3.0 reached 70.64%, which was 6.4% greater than that of conventional learning. These results confirm that visual programming-based learning media can significantly improve students' learning outcomes in informatics subjects at the junior high school level.

Table 3. Hypothesis test results

	Experiment Gainscore	Control Gainscore
Mean	14.8	4.77
Variance	104.92	12.87
Observations	30	30
Hypothesized Mean Difference	-	-
Df	36.01	-
t-stat	5.06	-
p(T<=t) one-tail	0.000006	-
t Critical one-tail	1.69	-
p(T<=t) two-tail	0.000012	-
t Critical two-tail	2.03	-

3.4 Discussion

The development of programming learning media via Scratch 3.0 in this study adopted a 4-D model consisting of the Define, Design, Develop, and Disseminate stages. The Define stage revealed the need for interactive and interesting learning media to help students understand the basic concepts of programming, as well as identify the difficulties teachers face in delivering programming material due to the limited learning media available. This finding is in line with those of Yuliansih et al. (2021) and Mellyzar et al. (2024), who emphasized that the feasibility of learning media can be assessed through expert evaluation involving aspects of design, content, and usability.

Media feasibility validation was conducted by three expert validators, with the results showing consistent improvement from the first to the second stage (Haryadi et al., 2021; Moreno, 2005). The material expert validators gave an average score of 4.35 (87%), the media expert validators gave a score of 4.15 (83.5%), and the learning

design expert validators gave a score of 4.2 (84.5%). These validation results confirm that the learning media met the eligibility criteria in the "very good" category on the basis of the established standards.

Sugiarto et al. (2023) and Mellyzar et al. (2024) confirmed that feasible learning media must meet the criteria of suitability for learning objectives, ease of use, and attractiveness for students through a comprehensive validation process. The design stage produces visual programming-based learning media via the Scratch platform, which is designed to facilitate understanding of basic programming concepts such as algorithms, branching, and looping (Salleh Hudin, 2023). Compared with the pretest, implementation at the development stage significantly increased learning outcomes, with posttest scores reaching 76.67% of the students completing the test; only 36.67% of the students achieved completeness. This increase indicates the effectiveness of media in facilitating visual programming learning (Assulamy et al., 2023; Cárdenas-Cobo et al., 2021; Sandoval-Reyes et al., 2011).

Statistical analysis revealed that learning media programming via Scratch 3.0 effectively improved students' learning outcomes, with significant differences between the experimental and control groups. This finding supports Calder (2019), who showed that Scratch is effective in improving concept understanding and problem-solving skills. Kazimoglu et al. (2012), Campbell and Atagana (2022), Mashishi and Ramaila (2024) and Zaranis et al. (2016) reinforced these findings by investigating the effectiveness of Scratch in teaching programming and computational thinking, which significantly improved the understanding of programming concepts. Papadakis et al. (2016) added that the use of visual programming tools such as Scratch can significantly improve learners' understanding of informatics concepts.

The effectiveness of the learning media reached 92.73% in the "very good" category on the basis of the evaluation of competency achievement and learning outcomes. The competency achievement aspect showed an increase in students' responses to questions and activities in tasks, reaching 100%; motivation and interest in learning media reached 100%; and understanding programming concepts reached 100%. Sandoval-Reyes et al. (2011), Noone and Mooney (2018), and Cárdenas-Cobo et al. (2021) stated that they facilitated the delivery of teaching materials containing complex materials. This study is in line with the multimedia learning theory proposed by Kassa et al. (2024), which emphasizes the importance of multimedia-based learning design in improving the understanding and retention of information. Moreno (2005) and Moreno-Leon and Robles (2016) reported that the application of multimedia learning principles can significantly improve students' learning outcomes. Sweller et al. (2019) confirmed that a good multimedia learning design can reduce the cognitive load and facilitate more efficient information processing.

Moreno-Leon and Robles (2016) showed that the use of visual programming tools can improve learners' computational thinking skills, especially in terms of problem solving and algorithmic logic. This approach encourages learners' creativity, as they can immediately see the results of their code in a visual form (Assulamy et al., 2023; Cárdenas-Cobo et al., 2021; Gresse von Wangenheim et al., 2021; Noone & Mooney, 2018; Sandoval-Reyes et al., 2011). Kassa et al. (2024) reinforce these findings by stating that multimedia integration in digital learning can increase learners' engagement and motivation to learn. Park and Shin (2019) and Pérez-Jorge and Martínez-Murciano (2022) emphasized the importance of using innovative and interactive learning media to improve learners' understanding and motivation. Effective media must be able to adjust to the characteristics of learners and the learning objectives to be achieved (Mashishi & Ramaila, 2024; Salleh Hudin, 2023; Wang et al., 2024). Research shows that the use of technology-based media can significantly improve learners' learning outcomes compared with conventional methods (Acevedo-Borrega et al., 2022; Kamalov et al., 2023; Naidu, 2003; Wang et al., 2024).

3.5 Implication

Programming learning media via Scratch 3.0 provides a practical solution to overcome teachers' difficulties in delivering programming materials. This learning media not only helps teachers overcome learning challenges but also encourages the development of 21st century skills in learners. The implementation of this learning medium creates an active and fun classroom atmosphere with effective communication between learners and teachers. The use of programming learning media via Scratch 3.0 makes learners feel happy and enthusiastic about learning so that the knowledge developed can motivate them to learn independently, creatively, and efficiently.

3.6 Limitations and recommendations

The product only contains one informatics learning material; therefore, further development is needed to cover more comprehensive materials. The learning media can be used only on computers and Android devices without iOS support, which limits accessibility for users on different platforms. The production of learning media was limited for

the purposes of this research. Recommendations for future research include the development of learning media that cover all informatics curriculum materials, the development of versions that are compatible with various platforms, including iOS, and wider scale implementation to test effectiveness in various educational settings. Programming learning media using Scratch 3.0 has been proven to meet the eligibility standards and improve the effectiveness of informatics learning, especially in algorithms and programming materials, so that it can be adopted as an effective learning tool in formal education.

4. Conclusion

In conclusion, this study succeeded in developing learning media programming using Scratch 3.0, which is feasible and effective in improving the learning outcomes of informatics subjects at Dr. Wahidin Sudirohusodo Junior High School. The development process using the 4-D model showed consistent validation results from three expert validators, all in the "Very Good" category. The effectiveness of the learning media showed a significant increase in learning outcomes, with a percentage of effectiveness reaching 92.73% in the "very good" category. These findings confirm the research hypothesis that visual programming learning media can improve students' learning outcomes in informatics subjects. Programming learning media using Scratch 3.0 has been proven to meet the standards of feasibility and effectiveness for improving learning outcomes in informatics subjects. The implementation of this learning medium can contribute to improving the quality of informatics education and the development of learners' digital skills in accordance with the demands of the digital era. Future research should explore the development of more comprehensive learning media with multiplatform support and implementation in various educational contexts.

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