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A Web-Based Flipped Classroom in Introductory Programming Education: Effects on Student Learning Outcomes

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ABSTRACT

This study examined the effectiveness of a web-based flipped classroom model in improving student learning outcomes in an Algorithms and Programming course, compared with conventional instruction. A quasi-experimental pretest–posttest control group design was employed, involving 64 students from the Informatics and Computer Engineering Education Program at Universitas Negeri Makassar. The experimental group received instruction through a web-based flipped classroom model, whereas the control group received conventional lecturer-led instruction. Data were analysed using descriptive statistics, assumption testing, an independent samples t-test, normalized gain (N-Gain), and Cohen's d effect size in R. The results showed that the experimental group achieved a higher mean post-test score (75.38) than the control group (57.81). An independent samples t-test indicated a statistically significant difference between the two groups ($p < .001$). The experimental group also achieved a higher N-Gain (0.499, moderate) than the control group (0.214, low), indicating greater improvement in learning outcomes under the web-based flipped classroom model. Cohen's d was 1.058, indicating a large and educationally meaningful effect. The study concludes that the web-based flipped classroom model was effective in improving student learning outcomes in the Algorithms and Programming course. Future research should examine additional explanatory variables, such as learning motivation and self-regulated learning.

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1. INTRODUCTION

The Algorithms and Programming course often represents a significant challenge for first-year students in informatics and computer engineering education. This course requires a strong understanding of logical concepts as well as practical programming skills; however, many students struggle to master abstract concepts such as variables, loops, conditionals, debugging, and algorithm design. These difficulties are pedagogically important because success in introductory programming depends not only on conceptual understanding but also on the ability to translate that understanding into computational problem solving and procedural application. International studies consistently report high failure rates in introductory programming courses (CS1), with an average of approximately 28–33% of students failing or dropping out (Bennedsen & Caspersen, 2019; Watson & Li, 2014). These outcomes are not only a matter of grades, but also relate to student retention and the quality of foundational computing education. Consistent with these global trends, empirical evidence from the Department of Informatics and Computer Engineering, Faculty of Engineering, Universitas Negeri Makassar, reveals that student achievement in the Algorithms and Programming course remains below expectations; of the 166 students enrolled, 22% received low or unsatisfactory grades (Karim et al., 2024). This local condition suggests that the problem is not merely theoretical, but also pedagogical in practice. Teacher-centered instructional methods often exacerbate these challenges, as they provide limited opportunities for meaningful interaction and independent practice prior to face-to-face sessions. More specifically, such approaches tend to compress explanation and practice into limited classroom time, thereby reducing opportunities for iterative coding practice, peer interaction, and formative feedback. Consequently, students experience persistent conceptual misunderstandings and low learning motivation (Armelia & Andayani, 2024).

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One instructional approach that has emerged in response to these challenges is the Flipped Classroom (FC) model. This method shifts content delivery outside of class through videos or online materials and utilizes classroom time for active learning activities such as discussions, problem-solving, and group collaboration (Schmid et al., 2023). In programming education, this model is especially relevant because it may free classroom time for debugging, guided coding practice, and collaborative problem solving. It also allows students to explore and understand course content more deeply before engaging with peers and instructors (Zuhaery & Hidayati, 2023), thereby fostering more participatory and meaningful learning experiences. Previous studies have shown that the flipped classroom method can improve learning outcomes, student motivation, and engagement in the learning process (Mohseni et al., 2024; Rahmah et al., 2021). A meta-analysis conducted by Ni et al., (2023) revealed that the flipped classroom model has a moderately positive impact on students' academic achievement, especially when supported by learning management systems and constructivist-based pedagogical approaches (Ni et al., 2023). Furthermore, the flipped classroom has been found to enhance students' self-directed learning (Mirlanda et al., 2019). However, the available evidence is not uniformly conclusive. The effectiveness of flipped classrooms often depends on implementation quality, student readiness, course design, and the quality of pre-class learning materials. In this context, the integration of information technology through the flipped classroom model is highly relevant. By offering flexible access to learning materials, students can manage their time more efficiently and study at their own pace. In programming education, such self-paced access is especially valuable because learners often need repeated exposure to procedural demonstrations and coding logic. The use of technology in flipped learning environments enables students to access learning content anytime and anywhere, without the limitations of time and space (Yulianti & Wulandari, 2021). The integration of web-based learning media within the flipped classroom model may further strengthen instructional effectiveness because web-based media can support both self-directed and collaborative learning by providing structured, on-demand access to course content. Previous studies have shown that the flipped classroom approach enhances cognitive engagement, academic performance, and higher-order thinking skills such as problem-solving and critical thinking (Chen et al., 2025; Huang et al., 2022).

Despite the growing body of literature demonstrating the effectiveness of flipped classroom models in various disciplines, empirical evidence in the context of Algorithms and Programming courses remains limited. Many previous studies have focused primarily on disciplines such as healthcare, business, and language education, while relatively few have investigated flipped classroom implementation in programming-related courses. This matters because programming courses involve abstract reasoning, iterative debugging, and procedural skill development, making their instructional demands distinct from many other disciplines. Furthermore, limited research has explored the integration of dedicated web-based learning media within flipped classroom environments for programming instruction. This is a meaningful gap, not only because such studies are still scarce, but also because it remains unclear how web-based flipped learning supports the transition from abstract programming concepts to practical coding performance. Dedicated web-based media may provide pedagogically important affordances, such as structured scaffolding, repeated practice, and immediate access to learning resources, all of which are especially relevant in programming education. Accordingly, there is a need for context-specific empirical evidence on whether and how web-based flipped classroom designs improve learning outcomes in introductory programming courses. In addition, research by Zhao et al. (2021) emphasized that the flipped classroom approach can enhance learning achievement, motivation, learning satisfaction, and self-efficacy among pre-service teachers. In their study on a Modern Educational Technology (MET) course, the experimental group using flipped classroom strategies significantly outperformed the control group in terms of practical tasks, knowledge transfer, and student perceptions. Although this context differs from introductory programming, the findings reinforce the view that flipped classroom approaches can support technology-mediated and skill-based learning.

The novelty of this study lies not merely in applying a flipped classroom model, but in examining a web-based flipped classroom as a single instructional construct in the context of introductory programming education. More specifically, this study contributes context-specific empirical evidence on the use of a web-based flipped classroom in an Algorithms and Programming course, a context that remains underrepresented in the flipped learning literature (Huang et al., 2022; Reyes et al., 2022). In addition, this study complements significance testing with practical effect measures, including normalized gain (N-Gain) and Cohen's d, to provide a more informative account of instructional impact in information technology education. Based on this background, this study

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examines the effectiveness of a web-based flipped classroom model in improving student learning outcomes in an Algorithms and Programming course. The study is intended to determine whether students who learn through a web-based flipped classroom achieve better learning outcomes than those who receive conventional lecturer-led instruction.

2. MATERIAL AND METHOD

Research Design

This study employed a quasi-experimental pretest–posttest control group design to examine the effectiveness of a web-based flipped classroom model on student learning outcomes in an Algorithms and Programming course. The use of a quasi-experimental approach was considered appropriate because the study was conducted in an authentic educational setting using intact classes rather than random assignment, thereby preserving the natural classroom context. Two groups were involved in the study: an experimental group, which received instruction through a web-based flipped classroom model, and a control group, which received conventional lecturer-led instruction. Prior to the intervention, both groups completed a pretest to assess their initial level of knowledge and to ensure baseline comparability. The intervention was then implemented over a specified instructional period, during which the experimental group engaged with online learning materials before class and participated in interactive, problem-solving activities during in-class sessions. In contrast, the control group followed a traditional instructional approach characterized by direct explanation and guided practice during class time. At the end of the intervention, a posttest was administered to both groups to measure changes in learning outcomes. The comparison between pretest and posttest scores within and between groups allowed for the evaluation of the effectiveness of the instructional model. Figure 1 presents the schematic diagram of the research design, illustrating the sequence of the pretest, treatment, and posttest phases for both groups (Armelia & Andayani, 2024).

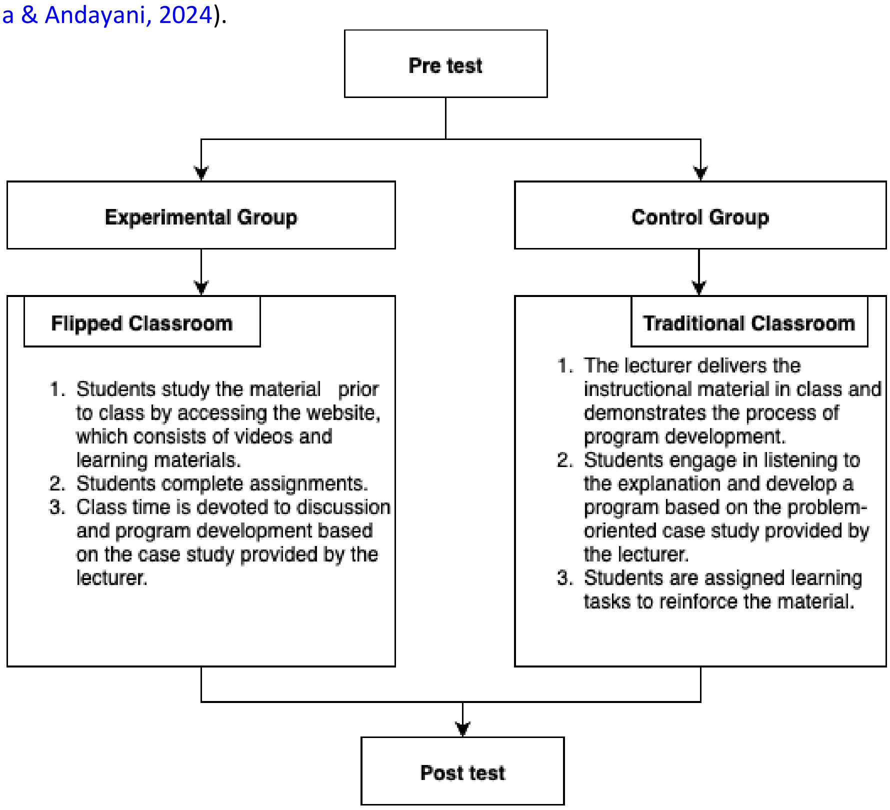

Figure 1. Schematic diagram illustrating the research design

Participants and Data Collection

This study was conducted during the odd semester of the 2024/2025 academic year, from August to December 2024, over eight instructional sessions at the Informatics and Computer Engineering Education

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Program, Universitas Negeri Makassar. The participants were undergraduate students enrolled in the Introduction to Algorithms and Programming course. A purposive sampling technique was employed to select two intact classes based on comparable initial characteristics, as indicated by their pre-test performance. From the available population, two classes with relatively similar baseline abilities were selected, with Class A assigned as the experimental group and Class B serving as the control group. A total of 64 students participated in the study, consisting of 32 students in each group, ensuring balanced group sizes for comparison and supporting the internal validity of the study design.

Data collection was carried out through the implementation of a web-based flipped classroom intervention and the subsequent assessment of student learning outcomes. A dedicated web-based learning platform, developed using the Bootstrap framework, served as the core instructional medium for the experimental group and featured structured weekly modules, instructional videos of approximately 30 minutes each, practice exercises, and visual illustrations of code execution to support students' understanding of programming logic. Students in the experimental group were required to access the platform and complete assigned learning activities prior to attending face-to-face sessions, allowing classroom time (150 minutes) to be used for interactive discussions, case analysis, collaborative problem-solving, and hands-on coding practice with instructor and peer feedback. In contrast, the control group received conventional face-to-face instruction of equal duration, consisting of lecturer-led explanations and in-class demonstrations without access to the web-based platform. Although both groups followed the same course content and instructional time, they differed in instructional delivery, enabling a systematic comparison of the effectiveness of the flipped classroom model (Huang et al., 2022; Armelia & Andayani, 2024).

Instruments and Procedure

The primary instrument used in this study was a researcher-developed learning outcome test designed to measure students' understanding of key concepts in algorithms and programming. The test consisted of 15 multiple-choice questions covering fundamental topics such as loops, conditionals, and functions, as well as one case-based problem-solving task that required students to design an algorithm using a flowchart with the Flowgorithm application and implement the corresponding program in C++. This combination of objective and performance-based assessment was intended to capture both conceptual understanding and practical programming skills. The case-based task was evaluated using a structured analytic rubric with a maximum score of 100 points, assessing the correctness and logic of the algorithm design (50%) and the accuracy of code implementation, including syntax and functionality (50%). Prior to its use, the instrument was reviewed to ensure content relevance and clarity, allowing for a comprehensive evaluation of students' higher-order thinking and problem-solving abilities (Huang et al., 2022; Reyes et al., 2022).

In addition to the assessment instrument, a dedicated web-based learning platform was developed as the core instructional medium for the flipped classroom model. The platform, built using the Bootstrap framework, featured structured weekly modules, instructional videos (approximately 30 minutes each), practice exercises, and visual illustrations of code execution to support students' understanding of programming logic. Students in the experimental group were required to access the platform and complete learning activities prior to attending face-to-face sessions, enabling classroom time (150 minutes) to be used for interactive discussions, case analysis, collaborative problem-solving, and hands-on coding practice with instructor and peer feedback. In contrast, the control group received conventional face-to-face instruction of equal duration, consisting of lecturer-led explanations and in-class demonstrations without access to the web-based platform (Armelia & Andayani, 2024). This difference in instructional approach allowed for a clear comparison of the effectiveness of the flipped classroom model supported by web-based learning tools.

Data Analysis Techniques

The pre-test and post-test data were analysed using both descriptive and inferential statistical techniques. Descriptive statistics included the calculation of the mean, standard deviation, minimum, and maximum scores in order to provide an initial overview of students' learning outcomes in both the experimental and control groups. Inferential analysis was then conducted to determine whether the observed differences between groups were statistically meaningful. Prior to hypothesis testing, the assumptions for parametric analysis were examined. Normality of the post-test score distributions in each group was assessed using the

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Shapiro–Wilk test, which is appropriate for relatively small sample sizes. A significance value greater than 0.05 indicated that the data were normally distributed. Homogeneity of variance was examined using Levene's test for both pre-test and post-test scores. A significance value greater than 0.05 in Levene's test indicated that the variances of the two groups could be considered homogeneous, thereby supporting the use of the independent samples *t*-test.

Hypothesis testing was conducted using an independent samples *t*-test to compare the post-test scores of the experimental and control groups. This test was intended to determine whether students who learned through the web-based flipped classroom model achieved significantly different learning outcomes from those who received conventional lecturer-led instruction. The decision criterion was based on a significance level of 0.05, with $p < 0.05$ indicating a statistically significant difference between groups. To complement significance testing, the Normalized Gain (*N*-Gain) and Cohen's *d* effect size were also calculated as supplementary indicators of instructional effectiveness. *N*-Gain was used to estimate the magnitude of improvement from pre-test to post-test (Wahab et al., 2021), using the following formula:

$$N\text{-}Gain = \frac{Posttest - pretest}{maximum\ score - pretest}$$

The resulting *N*-Gain values were interpreted according to established categories, namely low, moderate, and high improvement. In addition, Cohen's *d* was calculated to estimate the magnitude of the difference between the experimental and control groups, thereby complementing statistical significance with an indicator of practical impact. This is particularly important in educational research because it helps determine whether observed differences are not only statistically significant but also educationally meaningful (Cohen et al., 2007). In general, effect size values around 0.20 are interpreted as small, around 0.50 as moderate, and 0.80 or above as large. All statistical analyses were conducted using the R programming environment.

3. RESULTS

Descriptive Statistics of Pre-Test and Post-Test Scores

Table 1. Descriptive Statistic of Pre-Test and Post-Test Scores

Group	Pre-Test				Post-Test			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Control	46.28	19.39	23	92	57.81	18.64	21	88
Experimental	51.75	18.85	24	88	75.38	14.26	35	100

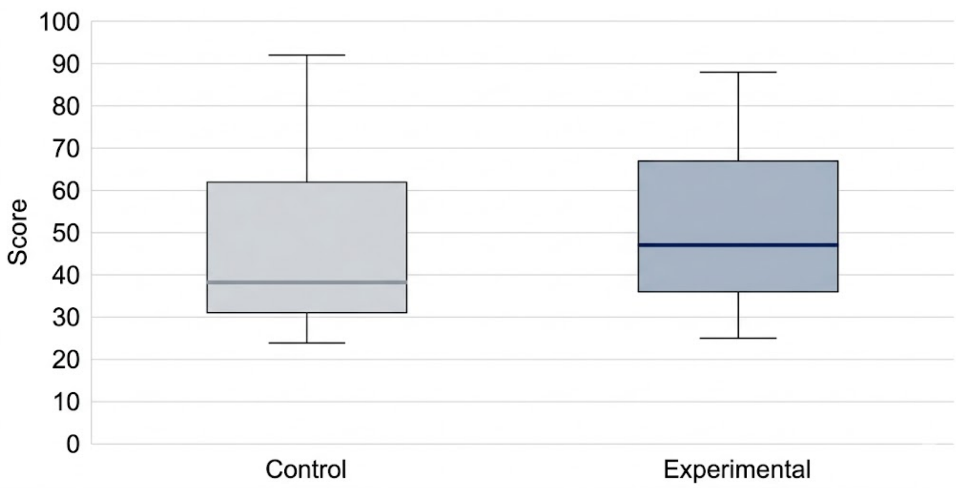

Figure 2. Score distribution for control and experimental Group (Pre-test)

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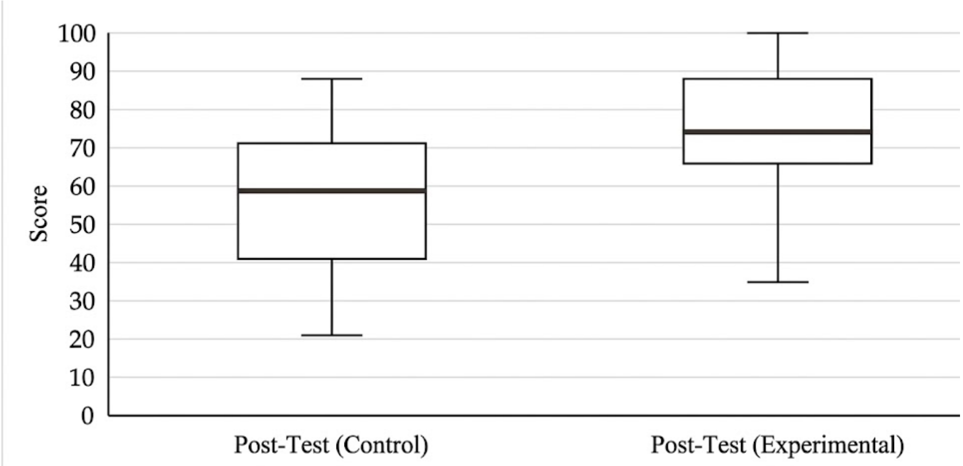

Figure 3. Score distribution for control and experimental Group (Post test Phases)

An initial descriptive analysis was conducted to examine students' baseline performance prior to the instructional intervention. As shown in Table 1, the experimental group had a mean pre-test score of 51.75 (SD = 18.85), whereas the control group had a mean pre-test score of 46.28 (SD = 19.39). The score ranges were 24–88 for the experimental group and 23–92 for the control group, indicating substantial variation in initial competencies across students. To clarify baseline comparability, an independent samples t-test was conducted on the pre-test scores. The result indicated that the difference between the two groups was not statistically significant, t(62) = 1.14, p = .257, suggesting that the groups were broadly comparable at the outset of the study (Nugrahani et al., 2023). After the intervention, the mean post-test score of the experimental group increased to 75.38 (SD = 14.26), whereas the control group obtained a mean post-test score of 57.81 (SD = 18.64). The mean difference between the two groups at post-test was therefore 17.57 points, indicating a substantial advantage for the experimental group (Armelia & Andayani, 2024).

The distribution of pre-test scores is presented in Figure 2 using a boxplot diagram. Both groups demonstrated relatively similar initial achievement levels, although minor differences in data dispersion were observed. The median score of the experimental group was approximately 45, slightly higher than that of the control group, which was around 38. The interquartile ranges (IQR) of both groups were relatively comparable, indicating a similar level of variability among students within each group. Although outliers were present in both groups, the overall distribution of scores remained within a reasonable range and did not display any significant deviations. This score distribution suggests that the initial competencies of participants in both groups were relatively balanced, making them suitable for comparison in evaluating the effectiveness of the instructional intervention applied to the experimental group (Armelia & Andayani, 2024; Huang et al., 2022). Such balance is crucial for ensuring the internal validity of the study, as differences observed in post-test outcomes can be more reliably attributed to the treatment rather than to pre-existing differences in student ability. After the intervention, a post-test was administered to evaluate the learning outcomes. The mean post-test score of the experimental group was 75.38 (SD = 14.26), while the control group scored an average of 57.81 (SD = 18.64), as shown in Table 1.

The analysis of post-test score distribution is presented in Figure 3, which compares learning outcomes between the control and experimental groups. The boxplot reveals a noticeable difference between the two groups. The experimental group generally achieved higher post-test scores with a more uniform distribution compared to the control group. The median score for the experimental group falls within the 75, whereas the control group has a median of approximately 69. Moreover, the experimental group exhibits a narrower interquartile range (IQR), indicating that most participants in this group achieved consistently high scores. In contrast, the control group shows a wider distribution, with scores ranging from approximately 21 to 88, reflecting greater variability in learning outcomes among participants. These findings suggest that the application of an innovative instructional approach, such as the web-based flipped classroom, was effective in enhancing

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learning outcomes (Armelia & Andayani, 2024; Nugrahani et al., 2023). The higher and more consistent scores observed in the experimental group indicate that the approach not only improved individual performance but also contributed to a more equitable understanding across the group of learners (Almassri & Zaharudin, 2023; Laidsaar-powel et al., 2024).

Normality Test

The normality of the post-test score distributions in both the experimental and control groups was examined using the Shapiro–Wilk test to verify the assumptions required for parametric analysis, particularly the independent samples t-test. The Shapiro-Wilk test is a widely used test for normality that evaluates whether the sample comes from a normally distributed population by comparing the observed distribution with a theoretical normal distribution (Shapiro & Wilk, 1965). A p-value greater than 0.05 suggests that the data do not significantly deviate from normality, and therefore, we can assume that the data are normally distributed, which justifies the use of parametric tests. In this study, the normality test results are presented in Table 2. For the control group, the Shapiro-Wilk W-value was 0.96, with a p-value of 0.24, indicating no significant deviation from normality. Similarly, for the experimental group, the Shapiro-Wilk W-value was 0.96, with a p-value of 0.29, also indicating that the data from the experimental group followed a normal distribution (Nugrahani et al., 2023).

Table 2. Result of Normality test (Shapiro-Wilk)

Group	W-value	p-value
Control	0.96	0.24
Experimental	0.96	0.29

As shown in Table 2, both groups yielded p-values greater than 0.05. Specifically, the control group had a p-value of 0.24, and the experimental group had a p-value of 0.29. According to the interpretation of the Shapiro-Wilk test, these p-values suggest that there is no significant evidence to reject the null hypothesis of normality. Therefore, it can be concluded that both the control and experimental groups have post-test score distributions that are approximately normally distributed (Nugrahani et al., 2023). Because the assumption of normality was met for both groups, it is appropriate to proceed with the use of parametric statistical tests, such as the independent samples t-test, for further analysis. Parametric tests rely on the assumption of normality in the data distribution, and since this assumption was satisfied, the results of the t-test can be considered valid and reliable for comparing the post-test scores between the two groups. In summary, the normality test confirmed that both groups' post-test scores followed a normal distribution, thus allowing for the use of parametric analyses in the subsequent steps of data analysis (Armelia & Andayani, 2024; Nugrahani et al., 2023).

Homogeneity of Variance Test

Levene's test was used to examine whether the variances of the experimental and control groups were equal, thereby assessing the assumption of homogeneity of variance required for the independent samples t-test. The homogeneity of variance assumption is crucial because the t-test assumes that the variability within each group is approximately the same. If this assumption is violated, it can lead to incorrect conclusions regarding the significance of group differences. Levene's test specifically checks whether the variance in each group is statistically equal by comparing the average deviations from the group means. A p-value greater than 0.05 indicates that the variances between the groups are not significantly different, and thus the assumption of homogeneity of variance is satisfied, allowing the use of parametric tests. In this study, Levene's test was applied to both the pre-test and post-test scores, with results showing that the F-value for the pre-test was 0.141 and the p-value was 0.707, while for the post-test, the F-value was 1.49 with a p-value of 0.223**.**

Table 3. Result of Homogeneity of Variance Test (Levene's Test)

Test	F-value	p-value
Pre-test	0.141	0.707
Post-test	1.49	0.223

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As presented in Table 3, both the pre-test and post-test scores yielded p-values greater than 0.05, suggesting that there was no significant difference in the variances between the experimental and control groups. Specifically, the p-values of 0.707 for the pre-test and 0.223 for the post-test indicate that the assumption of equal variances was not violated. Therefore, we can confidently conclude that the variances between the groups were homogeneous, which supports the use of parametric tests such as the independent samples t-test. This result is critical because it ensures that the t-test, which assumes homogeneity of variance, can be applied without violating its assumptions. The confirmation of homogeneity of variance, therefore, strengthens the validity of the subsequent analyses and supports the interpretation of the statistical tests for further hypothesis testing (Laidsaar-powel et al., 2024; Armelia & Andayani, 2024).

Independent Sample t-test

Independent samples t-test results were used to compare the post-test scores of the experimental and control groups and to determine whether the intervention produced a statistically significant difference in learning outcomes. The assumption underlying this test is that the data in each group are normally distributed and that the variances of both groups are homogeneous, both of which were confirmed in the previous tests (normality and homogeneity of variance). The purpose of this t-test was to assess whether the web-based flipped classroom model had a meaningful impact on student learning outcomes compared to the traditional, instructor-led approach used in the control group. A statistically significant result would suggest that the flipped classroom model led to better learning outcomes for students in the experimental group (Huang et al., 2022; Laidsaar-powel et al., 2024).

Table 4. Results of Independent Samples t-test on Post-test Scores

Comparison	t	df	p-value
Experimental vs Control	4.23	62	$p < .001$

As presented in Table 4, the results of the independent samples t-test yielded a t-value of 4.23 with 62 degrees of freedom (df) and a p-value of $p < .001$. Since the p-value is less than 0.001, it is highly significant, indicating a statistically significant difference between the post-test scores of the experimental and control groups. Specifically, this means that the experimental group, which received the web-based flipped classroom intervention, outperformed the control group, which received traditional instruction, by a substantial margin. The significant t-value suggests that the observed difference in post-test scores was unlikely to be due to random chance, thereby supporting the conclusion that the intervention had a meaningful effect on improving student learning outcomes. These results indicate that the flipped classroom model, when paired with web-based learning materials, was associated with significantly higher learning outcomes compared to the traditional teaching method (Armelia & Andayani, 2024). These findings reinforce the effectiveness of the flipped classroom model in enhancing student learning in an introductory programming course (Nugrahani et al., 2023). The large and statistically significant difference in post-test scores supports the argument that the experimental group benefited from the flipped classroom approach, which allowed more active engagement and more frequent practice opportunities compared to the traditional lecture-based method used in the control group. Thus, the results provide strong evidence in favor of the flipped classroom as a more effective instructional method for improving student outcomes in this specific context (Almassri & Zaharudin, 2023; Armelia & Andayani, 2024).

Comparison of Learning Gains Between the Control and Experimental Groups

Learning improvement in the control and experimental groups was compared using the N-Gain approach, which measures the relative improvement in students' learning outcomes based on their pre-test and post-test scores. The N-Gain is calculated by subtracting the pre-test score from the post-test score, then dividing by the maximum possible improvement (Hake, 1998). The N-Gain formula provides a standardized measure of improvement that allows for a more meaningful comparison between groups, regardless of the baseline differences. In this study, N-Gain was used as a supplementary indicator of learning improvement, complementing the statistical analysis from the independent samples t-test. It is particularly useful in illustrating the extent of improvement in both groups, as it provides a clear measure of how much students have learned relative to their initial performance (Armelia & Andayani, 2024). As shown in Table 5, the experimental group

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achieved an N-Gain of 0.499, which falls into the moderate category, indicating a substantial improvement in learning outcomes. In contrast, the control group had an N-Gain of 0.214, which is classified as low improvement. These results suggest that the experimental group, which received the web-based flipped classroom intervention, demonstrated significantly greater improvement in learning outcomes compared to the control group, which received traditional, instructor-led instruction. The difference in N-Gain scores further supports the finding that the flipped classroom model, with its self-paced learning materials and active in-class problem-solving, was more effective in enhancing student learning than the conventional teaching method (Armelia & Andayani, 2024; Laidsaar-powel et al., 2024).

Table 5. Analysis of N-Gain in Control and Experimental Groups

Group	N-gain	Category
Control	0.214	Low
Experiment	0.499	Medium

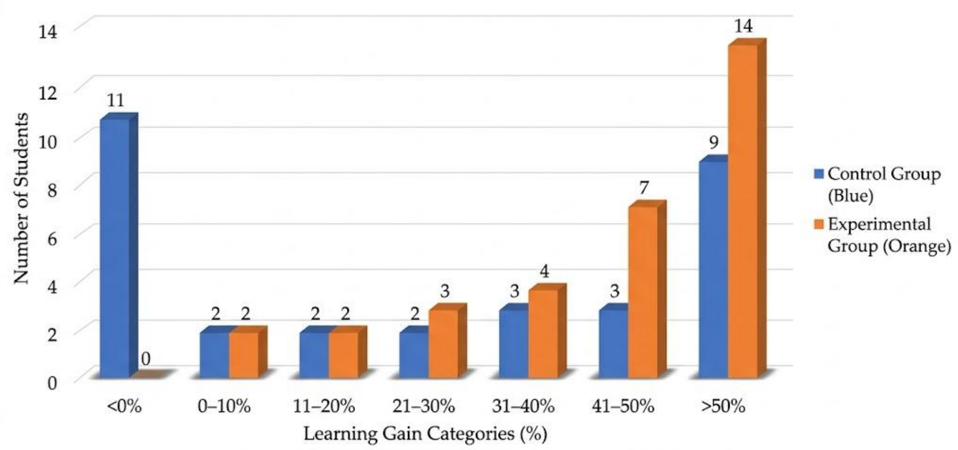

Figure 4. Learning gains pertentage improvement Control dan Experimental Group

In addition to the statistical comparison, Figure 4 provides a visual representation of the percentage improvement in learning gains across students in both groups. As illustrated in the figure, the experimental group showed a greater proportion of students achieving higher levels of improvement. Specifically, 14 students in the experimental group reached an N-Gain greater than 50%, while only 9 students in the control group achieved the same level of improvement. This suggests that the flipped classroom model resulted in a more consistent and substantial learning progress across students (Almassri & Zaharudin, 2023). In contrast, 11 students in the control group experienced negative gains (< 0%), meaning that their post-test scores were lower than their pre-test scores, while no students in the experimental group experienced negative gains. This discrepancy indicates that the web-based flipped classroom model not only led to greater average improvement but also provided more consistent positive learning outcomes across the experimental group (Almassri & Zaharudin, 2023). The results from both the N-Gain analysis and the visual representation in Figure 4 underscore the positive impact of the web-based flipped classroom model on student learning outcomes. (Huang et al., 2022) The experimental group not only showed greater overall improvement but also had fewer instances of negative learning progress, suggesting that the intervention supported more consistent, positive learning gains among students. This reinforces the earlier findings from the independent samples t-test and highlights the effectiveness of the flipped classroom model in improving student engagement and learning outcomes in the Algorithms and Programming course (Laidsaar-powel et al., 2024).

Effect Size of the Web-Based Flipped Classroom Intervention

Effect size analysis using Cohen's d was conducted to complement the earlier significance testing by quantifying the magnitude of the difference in post-test learning outcomes between the experimental and control groups. Effect size is a crucial statistic in educational research because, while p-values from statistical

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tests indicate whether an effect is likely due to chance, effect size measures the magnitude of the effect itself, helping to assess the practical significance of the findings. Cohen's d is particularly useful for understanding the size of the difference between two groups in terms of standard deviation units, providing a clear indication of how large the observed difference is in real-world terms (Cohen, 1988). A value of Cohen's d of 0.2 typically represents a small effect, 0.5 a medium effect, and 0.8 or higher a large effect, suggesting that the higher the Cohen's d value, the more meaningful and substantial the difference between groups. In this study, the Cohen's d value was calculated based on the difference in post-test scores between the experimental and control groups, which yielded a Cohen's d = 1.058. According to Cohen's et al., (2007), this value falls well above the threshold for a large effect, indicating that the difference between the two groups was not only statistically significant but also educationally meaningful. This result suggests that the intervention (specifically, the web-based flipped classroom model) had a strong and substantial impact on the students in the experimental group, leading to significantly better post-test performance compared to the control group. The large effect size further reinforces the validity of the finding that the flipped classroom model was highly effective in improving student learning outcomes. The magnitude of Cohen's d = 1.058 means that the difference between the post-test scores of the experimental and control groups is more than 1 standard deviation (Nugrahani et al., 2023; Laidsaar-powel et al., 2024). This is a notable difference, indicating that the experimental group showed a substantially higher level of improvement in learning outcomes. The large effect size further underscores the practical significance of the flipped classroom model in enhancing both conceptual understanding and practical programming skills in an introductory programming course (Nugrahani et al., 2023; Laidsaar-powel et al., 2024). In practical terms, this suggests that the flipped classroom model could be considered a highly effective pedagogical approach for improving student performance, providing strong evidence that the intervention had a meaningful educational impact beyond just statistical significance

4. DISCUSSION

Effectiveness of the Web-Based Flipped Classroom and Its Pedagogical Mechanism

The findings of this study suggest that the web-based flipped classroom model was associated with significantly higher learning outcomes in the Algorithms and Programming course. This interpretation is further supported by the independent samples *t*-test (Table 4), which showed a statistically significant difference between the experimental and control groups (t = 4.23, p < .001), indicating that the higher post-test performance of the experimental group was not merely descriptive but also inferentially supported. The practical importance of this result is further reinforced by the large effect size (Cohen's d = 1.058), suggesting that the intervention was not only statistically significant but also educationally meaningful. These findings are consistent with previous studies showing that flipped classroom approaches can promote active student engagement and deeper conceptual understanding through collaborative classroom activities (Armelia & Andayani, 2024; Nugrahani et al., 2023; Syajili & Abadi, 2021). At the same time, the present study adds more specific evidence from introductory programming education, suggesting that structured web-based support may be especially useful for translating pre-class exposure into meaningful in-class practice.

In the context of this study, the use of web-based learning media appears to have supported flexibility and accessibility for independent study, allowing classroom time to be used more productively for active learning (Laidsaar-powel et al., 2024). This interpretation is consistent with Ningsih & Wardani (2021), who reported that web-based learning platforms enable students to access learning materials anytime and anywhere. In programming education, however, such flexibility is not only a matter of convenience. Self-paced access may have enabled repeated exposure to programming logic, procedural demonstrations, and step-by-step explanations, which are particularly important in introductory coding contexts where students often need repeated review before they can apply concepts confidently in practice (Almazova et al., 2019). The findings also offer a plausible explanation of the learning mechanisms underlying the observed improvements. The integration of web-based features and in-class activities was intended to support key processes in programming learning, including scaffolded practice, rapid feedback, and structured problem solving (Reyes et al., 2022). The platform offered step-by-step instructional materials, practice tasks, and quizzes that functioned as comprehension checks, allowing students to monitor their understanding before attending class (Hamamura et al., 2023). During face-to-face sessions, instructional time was not reduced but rather optimised for guided coding practice, discussion, and collaborative problem solving. This design may have helped students identify misconceptions

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earlier and engage more deeply with programming tasks through support from both peers and instructors. Although these processes were not directly measured, the findings can reasonably be interpreted as consistent with this instructional logic (Almassri & Zaharudin, 2023).

Learning Improvement and Contribution to Programming Education

Additional evidence of learning improvement was provided by the N-Gain analysis (Table 5), which showed that the experimental group achieved a moderate level of gain, while the control group demonstrated a low level of improvement. This pattern supports the main post-test comparison by indicating that the web-based flipped classroom model was associated not only with higher final scores but also with stronger overall learning progress (Tosun & Gönen, 2024). This finding is in line with Rifaldi et al. (2024), who reported that the flipped classroom method contributes significantly to student learning outcomes.

In the present study, the gain distribution also suggests that the intervention supported more consistent learning progress across students. The absence of negative gains in the experimental group, together with the broader spread of positive gains relative to the control group, points to more consistently positive learning outcomes under the web-based flipped classroom model. However, this pattern should be interpreted cautiously. It is more appropriate to describe the findings as evidence of more consistent learning progress rather than as proof of equalised understanding or equitable learning gains. Similarly, the alignment with Nopiyanto et al. (2021), who emphasised that flipped classroom approaches can enhance students' sense of learning responsibility, should be understood as an interpretive extension rather than a direct finding of the present study, since learning responsibility was not measured here. In the context of informatics education, this study contributes to the growing body of research indicating that flipped classroom approaches can positively affect programming learning (Chiu et al., 2023; Taşpolat et al., 2021). More specifically, the present findings suggest that structured web-based scaffolding (including pre-class modules, comprehension checks, and guided in-class coding activities) may be particularly valuable in introductory programming courses, where students must move from abstract concepts to applied problem solving (Beniczky et al., 2020; Almanova et al., 2019). This point is important because programming courses differ from many other disciplines in that they require repeated practice, iterative debugging, and procedural reasoning. Accordingly, the present study contributes context-specific evidence showing that the combination of flipped pedagogy and dedicated web-based support can be especially relevant for foundational programming education (Beniczky et al., 2020).

Practical Implications, Limitation, and Futur Directions

The findings of this study offer important practical implications for higher education. In terms of instructional planning, the results underscore the need to reconsider the structure of classroom activities in introductory programming courses. Shifting content delivery to pre-class sessions through web-based media enables face-to-face time to be used more effectively for problem solving, peer collaboration, and guided coding practice. Lecturers are encouraged to incorporate interactive elements such as quizzes or comprehension checks into web-based platforms in order to reinforce pre-class learning and monitor students' readiness before classroom sessions begin. More broadly, the findings suggest that the effectiveness of flipped classroom instruction depends not only on moving content outside class, but also on carefully designing the relationship between pre-class preparation and in-class practice (Reyes et al., 2022; Laidsaar-powel et al., 2024). Several limitations should also be acknowledged. First, the sample size was relatively small (32 participants per group), which may limit the generalisability of the findings. Second, the intervention was conducted over a single semester, preventing conclusions about long-term retention and skill transfer. Third, the study primarily examined learning outcomes without considering potential mediating variables, such as motivation, self-efficacy, and self-regulated learning. This limitation is important because some of these constructs may help explain why flipped classroom approaches work differently across learners and contexts. Fourth, the web-based learning platform still requires further development and may be better understood as a platform with adaptive potential rather than as a fully adaptive learning medium in its current form. Future research should therefore examine flipped classroom implementation over longer periods and in a broader range of programming-related contexts. It would also be valuable to include additional explanatory variables, such as learning motivation, self-regulated learning, and confidence in engaging with programming tasks, in order to clarify the mechanisms that mediate

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improvement. Comparative studies across different introductory computing courses may further help establish how web-based flipped classroom designs can best support programming education in higher education settings.

5. CONCLUSION

This study found that the implementation of a web-based flipped classroom model was associated with significantly higher student learning outcomes in the Algorithms and Programming course. Specifically, the experimental group achieved a higher post-test mean than the control group, and the independent samples *t*-test confirmed that this difference was statistically significant ($t = 4.23$, $p < .001$). The experimental group also demonstrated a moderate normalized gain (N-Gain = 0.499), whereas the control group showed a low gain (N-Gain = 0.214). In addition, the effect size analysis revealed a large effect (Cohen's $d = 1.058$), indicating that the intervention was not only statistically significant but also educationally meaningful in practical terms. These findings suggest that combining self-paced web-based learning with active in-class problem solving can support both conceptual understanding and practical programming performance, as assessed in this study. Furthermore, the results highlight important pedagogical implications. Effective implementation of the flipped classroom model requires well-structured pre-class materials, the inclusion of short online quizzes or comprehension checks, and the optimisation of face-to-face sessions for guided problem solving, discussion, and collaborative learning. Such an approach helps students come to class better prepared and engage more deeply in meaningful learning activities. This study contributes to the growing body of evidence supporting the use of flipped classroom approaches in informatics education, particularly in programming courses, by providing quasi-experimental evidence from an introductory Algorithms and Programming course. However, as existing evidence remains context-dependent, further research is needed to examine the long-term impact and applicability of this model across different courses and educational settings.

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