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Integrating flipped classroom into website-based instruction: Effects on students' learning interest in respiratory system education

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ABSTRACT

This study aims to develop a website-based learning medium integrating the flipped classroom model for respiratory system instruction, following the ADDIE model, and to examine its effectiveness in enhancing eleventh-grade students' learning interest compared with conventional instruction. A Research and Development approach was combined with a quasi-experimental non-equivalent control-group design. Participants were 25 students in a small-scale trial and 80 students in a field trial, split into an experimental group ($n = 40$) taught with the flipped classroom website and a control group ($n = 40$) taught with the 5M scientific approach (observing, questioning, gathering information, associating, and communicating) and a textbook. Learning interest was measured with a validated five-point Likert questionnaire and analyzed using paired t-tests, the Mann-Whitney U test, and normalized gain (N-Gain) scores. The experimental group achieved an N-Gain score of 0.86, a high category, compared with 0.54, a moderate category, for the control group; both increases were statistically significant, $p < 0.001$, and the between-group difference was also significant, Mann-Whitney $U = 20.00$, $p < 0.001$. These results indicate that the website-based flipped classroom medium produced a substantially larger improvement in learning interest than conventional instruction and is effective for the respiratory system topic. Broader implementation is recommended, preceded by field trials in schools with comparable digital infrastructure.

INTRODUCTION

21st-century education demands a fundamental transformation of learning, particularly by innovative, adaptive digital technologies that are geared toward developing students' competencies-enabling them to compete and surpass the capabilities achieved through conventional lecture-based learning (Ng et al., 2023; Nhleko et al., 2025; Ridlo et al., 2022). Technology-based learning is one of the innovations in the learning process included in the agenda of Sustainable Development Goal 4 (SDG 4) because it implements a student-centered learning process (Fauzan et al., 2021; Indarta et al., 2022; Jasman et al., 2024; UNESCO., 2023). However, in many schools, the implementation of technology in the learning process remains hindered, leading to the continued use of conventional methods that tend to make students passive and unmotivated (Akram et al., 2022; Prakash, 2024; Satria et al., 2024). Therefore, there is a need to develop digital learning media that can make students more active and independent (Permatasari et al., 2024). One form of interactive technology-based learning media is a website that can be integrated with computers and smartphones (Adrian & Saputra, 2025; Ferdiansyah & Irfan, 2021). Additionally, it can present relevant and engaging visual content, thereby enhancing students' motivation and interest in learning (Mulyati, 2021; Paramitha et al., 2023). Thus, the development of web-based learning media represents a promising solution for creating an interactive learning environment, engaging students through student-centered learning, and making the process enjoyable, thereby increasing students' interest in learning (Haiyudi et al., 2025; Priani & Pertiwi, 2024; Rosbina et al., 2025)

Interest in learning is one of the most important internal factors for success and student engagement in the learning process. Students with high learning interest can determine the quality of learning achieved because learning interest makes students interested, attentive, and earnest in studying something that appeals to them (Awalia et al., 2021; Deci et al., 2000; Harefa et al., 2022; Warkintin et al., 2021). Other findings also indicate that high student learning interest is characterized by focused attention, enjoyment, active engagement, and perseverance in the face of learning challenges (Alfaris et al., 2025; Guo & An, 2025; Kahu et al., 2017). Students' interest in learning does not emerge or increase on its own; one factor that can enhance students' interest in learning is the use of instructional materials and learning media (Fatimah & Seriwati, 2024; Ningrum & Dharin, 2026; Rachmavita, 2020; Rachmawaty et al., 2026). However, field observations reveal that students' interest in learning remains low, as evidenced by a lack of enthusiasm in class, a lack of seriousness in listening to the teacher's explanations, and low academic achievement scores (Guo & Fryer, 2025). This is supported by other studies Kalogiannakis et al. (2021), which also indicate that students' interest in biology is relatively low due to the subject's abstract nature, thereby necessitating innovative pedagogical interventions. Therefore, appropriate learning strategies and media are needed to support and enhance students' interest in learning.

Interactive digital learning media can significantly increase students' enthusiasm, motivation, and interest in learning compared to students who engage in conventional learning (Ariandini et al., 2023; Ng et al., 2023; Satria et al., 2024). One subject that requires interactive digital learning media is the respiratory system, which is complex and difficult to understand. Furthermore, the respiratory system curriculum involves highly complex concepts, encompassing physiological processes such as lung ventilation, gas exchange, and the transport of oxygen and carbon dioxide, as well as respiratory regulation by the nervous system (Awalia et al., 2021). Concretely, this complexity creates two recurring obstacles for students: first, distinguishing the anatomical structures and functions of the respiratory organs from one another, since several organs perform closely related roles in a single continuous process (Paramitha et al., 2023); and second, connecting abstract, internal physiological events, such as gas diffusion across the alveolar membrane, that cannot be directly observed in the classroom (Tapia et al., 2019). The complexity of this material is reflected in learning outcomes, as shown by Aloahyt et al. (2022), whose students

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scored on average below the minimum passing score of 75. Students also struggle to remember the sequence and names of the respiratory organs, which further reduces their interest as the material feels difficult. Because these processes cannot be observed directly, they must be visualized accurately to be understood comprehensively (Tapia et al., 2019). Respiratory system material therefore needs to be paired with technology-based learning media capable of visualizing and representing these abstract concepts. In line with this, Kleftodimos (2024) and Paramitha et al. (2023) found that visualizing abstract material can significantly improve students' conceptual understanding and interest learning.

Developing technology-integrated learning materials is not sufficient on its own; the instructional model used must also be improved so that the technology is used effectively, for example through the flipped classroom model. The flipped classroom is an instructional model that inverts the conventional sequence of classroom activities: students first study core material independently, outside class, through pre-recorded videos or digital resources, and class time is then reserved for active, teacher-facilitated activities such as discussion, problem-solving, and collaborative work that reinforce and extend that material (Akçayır et al., 2018; Bergmann et al., 2012; Naing et al., 2023). The model is student-centered and is designed to improve learning quality (Annajmi et al., 2024). Flipped classroom model also helps students engage with instructional videos and interactive digital resources before in-class instruction, so classroom time can be focused on active learning activities such as discussion, problem-solving, and collaborative learning (Akçayır et al., 2018; Limaymanta et al., 2021; Lu et al., 2023; Shen et al., 2022; Yao et al., 2025). The flipped classroom is grounded in constructivist learning theory, because students construct their own understanding by connecting new material to prior knowledge, giving them repeated, self-paced access to core content before class allows this construction process to happen at the students' own pace, while the teacher's role shifts from a transmitter of information to a facilitator of the students' active, self-directed learning during class (Fuchs, 2021; Samavi et al., 2020; Zaki et al., 2024). This flipped classroom model has two key phases: the first phase encourages students to engage in independent learning outside the classroom before and after in-class instruction through digital platforms. The second phase involves students reinforcing previously studied concepts and material through more active and effective in-class learning to make the learning experience more meaningful (Annajmi et al., 2024). Additionally, the implementation of the flipped classroom model has also been shown to improve academic achievement, self-directed learning, critical thinking skills, and interest in learning across various fields of study (Lu et al., 2023; Rahmatika et al., 2024; Yao et al., 2025; Zulhamdi et al., 2022). One technology used in the flipped classroom model is web-based.

The integration of web-based technology can expand the learning environment because it is flexible, easily accessible anytime and anywhere, and more interactive, as it can be tailored to the needs of the students' learning process (Osadcha et al., 2021; Rasheed et al., 2020). A website is proposed here, specifically, as the delivery platform for the flipped classroom because it is the one medium that can simultaneously satisfy the three requirements raised above: continuous accessibility outside class hours for independent pre-class study, visual representation of abstract respiratory processes through video and animation, and structured, teacher-designed sequencing of pre-class, in-class, and post-class activities within a single platform, a combination that a printed module or a stand-alone video cannot provide on its own. Ekayana et al. (2021) and Mulyati (2021) similarly found that a website-based Learning Management System (LMS) can manage learning activities and outcomes and facilitate teacher-student interaction comfortably, efficiently, and flexibly. Web-based learning also allows students to review complex material as needed, such as the respiratory system (Al-Zahrani, 2024; Anjali et al., 2024; Martin-Alguacil et al., 2025). This is reinforced by Wulandari et al. (2025), whose needs analysis of 108 eleventh-grade science students found that the great majority reported existing handbooks insufficient and had difficulty understanding a comparably complex human physiology topic (the reproductive system), and that most students wanted an independent, interactive digital resource to supplement classroom

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instruction, a pattern consistent with the respiratory-system difficulties reported in the present study. Mufidah & Habibi (2022) likewise found that in an inquiry-based context, learning through the Google Sites platform is highly effective because it simultaneously enhances students' learning autonomy, learning outcomes, and motivation, since it allows flexible review of material and helps students come to class better prepared. Technology-based flipped classroom learning using a website platform is therefore highly relevant for implementation.

Relatively few previous studies have implemented a website-based flipped classroom model specifically designed to enhance learning interest in the respiratory system; most have focused on learning outcomes instead (Ayunda et al., 2024; Jasman et al., 2024). Previously developed technological products generally took the form of e-modules or flipbooks with pre-class, in-class, and post-class features structured according to the principles of the flipped classroom. This study therefore pursues two explicit objectives, in direct correspondence with the R&D-plus-quasi-experimental design described in the methods section: (1) to develop a flipped classroom-based website for human respiratory system material using the ADDIE model, and (2) to test the effectiveness of that website, once developed, in increasing students' learning interest relative to conventional instruction. Research by Achru (2019) indicates that interest is a factor driving student success in learning. Furthermore, this study is expected to contribute by providing practical and effective guidelines that can be widely adopted, as teachers' creativity in delivering content through media is a factor that can influence students' interest in learning (Mulyati, 2021). The content presented on the website can capture students' interest in learning because it allows for the inclusion of visualizations of abstract concepts, engaging reading materials, interactive quizzes, and discussion forums accessible to all students regardless of operating system digital. Additionally, in line with the requirements of the Merdeka Curriculum implementation, the use of a flipped classroom-based website is expected to shift the learning paradigm toward a student-centered approach, thereby making students more active before, during, and after the learning process (Akçayır et al., 2018; Bergmann et al., 2012; Mufidah & Habibi, 2022).

METHODS

Research Design

This study employed a Research and Development (R&D) approach combined with a quasi-experimental design. The product-a website-based learning resource using the flipped classroom model for respiratory system content-was developed using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The five ADDIE stages were carried out as follows. (1) Analysis: need and curriculum analysis, conducted through classroom observation and analysis of student learning-outcome data on the respiratory system topic, to confirm the topic's conceptual complexity and the students' low learning interest reported in the Introduction. (2) Design: drafting the website's information architecture, storyboards, and instrument blueprint, including the layout of the five interactive features (Biolab, Bioquiz, Biothink, Bioreview, and Bioinformation) and the mapping of pre-class, in-class, and post-class content to each stage of the flipped classroom. (3) Development: producing the website content (concept-representation videos, text material, and quizzes) and instruments, followed by expert validation by a media specialist, a subject-matter expert, and a high school biology teacher, and revision based on their feedback. (4) Implementation: delivering the validated product first in a small-scale trial (n = 25) to assess readability and usability, and then in the field trial (n = 80) described below. (5) Evaluation: formative evaluation at each stage (expert validation, small-scale trial) to revise the product, and summative evaluation of the field-trial data to determine the product's effectiveness in increasing learning interest.

The product-effectiveness testing phase used a non-equivalent control group design, a quasi-experimental design in which the experimental and control groups are not individually randomized but are compared through pretest and posttest measurements (Creswell et al., 2018).

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This design is more precisely described as a quasi-experiment with cluster (class-level) assignment, since two intact classes, rather than individual students, were assigned to the experimental and control conditions. This design was chosen because school learning conditions do not allow for full randomization of individual students (Ayunda et al., 2024). Thus, the research process consists of two phases: first, the product development phase; second, the product effectiveness testing phase, including limited and field trials. The mapping of the pretest-posttest control group design is shown in Table 1.

Table 1

Control group pretest-posttest design.

Class	Pretest	Treatment	Posttest
Experiment	O1	X	O2
Control	O1	Y	O2

Information: O1 = Pretest for the experimental class and the control class; O2 = Posttest for the experimental class and the control class; X = Learning biology using a website (flipped classroom); Y = Biology instruction using textbooks (5M scientific approach).

Further details regarding the differences in teaching methods and instructional materials between the experimental and control classes are provided in Table 2.

Table 2

Comparison of teaching methods and materials in the experimental and control classes.

Class	Learning Method	Teaching Materials
Experiment	Flipped Classroom	Website
Control	5M Scientific	Textbook

Implementation in the two classes proceeded as follows over four meetings covering the respiratory system topic. In the experimental class, each meeting followed three flipped classroom stages: (a) a pre-class stage, in which students independently studied the assigned video and reading material on the website at home and completed a short online check; (b) an in-class stage, in which class time was used for discussion, problem-solving activities, and the Biolab/Biothink features to deepen the concepts already introduced; and (c) a post-class stage, in which students completed the Bioquiz and Bioreview features to reinforce and consolidate what had been learned. In the control class, each meeting followed the five stages of the 5M scientific approach (observing, questioning, gathering information, associating, and communicating) using the textbook as the main resource, with the teacher delivering material through direct explanation and structured worksheet activities. Both classes received the same amount of instructional time and covered the same respiratory system sub-topics at each meeting, so that the two conditions differed in learning method and medium, not in content coverage or time allocation.

Population and Samples

The population in this study consisted of all 11th-grade science students in Tulungagung Regency who were studying the respiratory system topic. For research-ethic reasons, the specific school is not named in this article; it is identified only as a public senior high school (SMA Negeri) in Tulungagung Regency, consistent with standard practice for reporting in minors in Indonesian school-based research. Sampling was conducted in two stages, corresponding to the two testing phases. First, a limited/small-scale trial involved 25 students selected by random sampling from within the participating school; this trial assessed the website's readability, usability, and students' initial responses before wider implementation. Second, the field trial involved two intact eleventh-

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grade science classes at that same school, each with 40 students (80 students' total: one experimental class and one control class); the population for the field trial is therefore the eleventh-grade science student body of the participating school, while the Tulungagung-wide description above characterizes the broader target population to which the findings are cautiously generalized. Class selection used a cluster random sampling technique with a lottery system, so randomization was performed at the class level rather than the individual level (Ayunda et al., 2024), because classes in schools are naturally formed units that cannot be randomized individually (Fraenkel et al., 2019).

Instruments

The research instrument used was a learning-interest questionnaire on a five-point Likert scale. This questionnaire measured three main aspects: students' interest in the media and materials, their attention during the learning process, and their active engagement in learning activities. A generic learning-interest questionnaire was deliberately chosen and adapted, rather than a subject-specific instrument, because the study's dependent variable is learning interest as a general motivational-affective construct, not respiratory-system content mastery (which was not measured in this study); the three-aspect structure (media/material interest, attention, active engagement) was selected because it directly parallels the flipped classroom's own three phases (pre-class, in-class, post-class), allowing each aspect score to be interpreted against a specific stage of the intervention. The use of Likert-scale-based instruments to measure engagement and learning interest in the flipped classroom context has been validated in various studies, including the research by (Mizza et al., 2025), which used a Likert scale survey with students in a social statistics course during the 2023 and 2024 academic years to assess the impact of the flipped learning model on student engagement and inclusion. The scores obtained are interpreted based on the scoring system and criteria presented in Table 3.

Table 3

Score interpretation and criteria.

Score Interval	Criteria
X > Mi + 1,5 SBi	Excellent
Mi + 0,5 SBi < M ≤ Mi + 1,5 SBi	Good
Mi – 0,5 SBi < M ≤ Mi + 0,5 SBi	Average
Mi – 1,5 SBi < M ≤ Mi – 0,5 SBi	Poor
X ≤ Mi – 1,5 SBi	Very poor

Source: (Ananda & Fadhli, 2018)

Information: M = actual score (the score achieved); Mi = ideal average = (ideal maximum score + ideal minimum score); SBi= standard deviation = (1/2) (1/3) (maximum ideal score – minimum ideal score); Maximum Ideal Score = ∑ criteria item x maximum score; Minimum Ideal Score = ∑ criteria item x minimum score.

Before being tested, all devices were first validated by three experts, including a media specialist, a subject matter expert, and a high school biology teacher. In addition to expert content validation, the internal consistency of the 40-item learning-interest questionnaire was tested using Cronbach's alpha, yielding α = .843, which exceeds the commonly accepted threshold for good reliability (Tavakol & Dennick, 2011), indicating that the questionnaire produced consistent scores across items before it was administered in the small-scale and field trials.

Data Collection and Analysis

Data were collected using non-test methods, specifically a product feasibility questionnaire administered to subject matter experts, media experts, and biology teachers, and a learning

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interest questionnaire; both utilized a Likert scale. The scale values and evaluation criteria for the product feasibility analysis are presented in Table 4.

Table 4
Likert scale rating criteria.

Scale Value	Evaluation Criteria
1	Very poor
2	Poor
3	Fair
4	Good
5	Excellent

Source: (Riduwan, 2013)

Next, the learning interest questionnaire was administered twice: a pre-test before implementation and a post-test after implementation. This procedure was applied to both the experimental and control classes. The pre-test data were used to verify that the initial conditions of both groups were equivalent prior to the intervention. Post-test data were used to assess learning interest after the intervention. The difference between the pre-test and post-test was used to calculate the gain score through N-Gain analysis. Students' responses to learning interest questions were transformed into quantitative data, as shown in Table 5.

Table 5
Scale values for the student learning interest questionnaire.

Agreement	Scale Score for Each Statement	
	Positive	Negative
Strongly Agree	5	1
Agree	4	2
Neutral	3	3
Disagree	2	4
Strongly Disagree	1	5

Source: (Riduwan, 2013)

Data analysis used descriptive analysis (mean, standard deviation, minimum, and maximum scores) to describe the distribution of learning-interest scores, and inferential analysis to test hypotheses about that distribution. Prerequisite tests, the Shapiro-Wilk normality test (appropriate for the sample size of 40 per class) and Levene's homogeneity test, were conducted before each hypothesis test; their results are reported narratively in the Results section, rather than in separate tables, to avoid duplicating the same significance values that already accompany each hypothesis test. Hypothesis testing used the Paired Samples T-Test to assess the significance of the pre-post difference within each class, and the Independent Samples T-Test (or its nonparametric alternative, the Mann-Whitney U test, when normality or homogeneity assumptions were not met) to assess the significance of the post-intervention difference between the experimental and control classes. To quantify the magnitude of these differences using the complete set of individual pretest and posttest scores, Cohen's dz (the mean difference score divided by the standard deviation of the difference scores) was calculated for each class's paired within-group comparison, and Hedges' g – Cohen's d corrected for small-sample bias (Hedges & Olkin, 1985) was calculated for the between-group comparison, using each participant's gain score (posttest minus pretest) rather than the raw posttest score alone, since a posttest-only

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comparison would not account for each class's own starting point in this non-equivalent-groups design (Cohen, 1988).

The increase in learning interest was analyzed using the normalized gain (N-Gain) score <g>, calculated as the ratio of the actual gain (posttest score minus pretest score) to the maximum possible gain (maximum score minus pretest score); the resulting scores and their established interpretation categories by Nismalasari et al. (2016), as presented in Table 6.

Table 6

Criteria for the N-Gain score index.

Score Range (g)	Category	Description
0,70 ≤ (<g>) ≤ 1.00	High	Significant improvement
0,30 ≤ (<g>) < 0.70	Medium	Moderate improvement
0,00 < (<g>) < 0,30	Low	Slight improvement
g = 0,00	No Change	No improvement occurred
-1,00 ≤ (<g>) < 0,00	Decrease	Performance declined

Modified from: (Nismalasari et al., 2016).

To determine effectiveness, the N-Gain score categories can be examined in terms of percentages, as shown in Table 7.

Table 7

Categories of interpretation of effectiveness of N-Gain scores.

N-Gain Percentage	Category
< 40%	Ineffective
40% – 55%	Less Effective
56% – 75%	Moderately Effective
> 76%	Effective

Source: N-Gain score × 100%; criteria modified from Sugiyono (2013).

In addition to the N-Gain criteria in Table 6, the magnitude of improvement can also be interpreted as a percentage of the maximum possible gain (N-Gain score × 100%), following the criteria in Table 7 (Sugiyono, 2013). This N-Gain-based percentage is a distinct measure from the "Percentage Increase" row reported later in Table 8, which instead expresses each group's N-Gain score as its proportional share of the two groups' combined N-Gain; the two percentages, reported separately in the Results, answer different questions and should not be conflated.

RESULTS AND DISCUSSION

Results of Product Development (ADDIE)

Consistent with the study's first objective, this subsection reports the product-development results before the effectiveness-testing results, following the ADDIE sequence described in the Methods section. Expert validation produced feasibility scores from the media specialist, subject-matter expert, and biology teacher on the Table 4 rating scale; the media specialist rated the website Good-to-Excellent on usability (M = 4.00), functionality (M = 4.15), and visual communication (M = 3.73); the subject-matter expert rated presentation quality as Excellent (M = 4.17), content feasibility as Good (M = 3.25), and language/communication as Good (M = 3.17); and the biology teacher rated usability (M = 4.00), functionality (M = 4.00), language/communication (M = 3.73), presentation (M = 4.00), and content feasibility (M = 4.00) all as Excellent, indicating the product

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was feasible from the media, content, and practitioner perspectives before proceeding to the small-scale trial. The website was then revised based on expert feedback before the small-scale trial. In the small-scale trial ($n = 25$), students' readability and usability responses were recorded on the same feasibility scale, and the results indicated the product was ready for field testing; the 25 students rated usability at $M = 4.38$, functionality at $M = 4.30$, and visual communication at $M = 4.30$, all in the Excellent category, and their open-ended comments were positive regarding ease of access and the Bioquiz/Biothink exercises, with suggestions to add more illustrative video content, which were incorporated before the field trial. The final website comprises five interactive features: Biolab (virtual respiratory-process simulations), Bioquiz (post-class formative quizzes), Biothink (in-class discussion and problem-solving prompts), Bioreview (post-class material review), and Bioinformation (supplementary text and video content), mapped to the pre-class, in-class, and post-class stages of the flipped classroom as described in the Methods section.

Descriptive Overview of Learning Interest

Before inferential testing, Table 8 summarizes the descriptive statistics for both classes, verified directly against the complete set of individual pretest and posttest scores in the Appendix. At pretest, the experimental class ($M = 51.00$, $SD = 4.60$) and control class ($M = 51.53$, $SD = 6.18$) had closely comparable mean learning-interest scores. A Mann-Whitney U test confirmed this baseline equivalence: the pretest difference between the two classes was not statistically significant, $U = 742.00$, $Z = -0.559$, $p = 0.576$, and Lavene's test indicated the two classes' pretest variances were also homogenous, $F(1,78) = 2.75$, $p = 0.101$, indicating that the two groups began from an equivalent baseline before treatment. At posttest, the experimental class mean rose to 93.09 ($SD = 3.69$) and the control class mean rose to 77.64 ($SD = 4.85$); both groups improved, but the experimental class improved by a larger margin.

Results of the Prerequisite Test Analysis

Prerequisite tests were conducted before each hypothesis test. For the within-group (paired) comparison, the Shapiro-Wilk normality test showed that all four pretest/posttest data (experimental pretest: $df = 40$, $p = 0.787$; experimental posttest: $p = 0.641$; control pretest: $p = 0.740$; control posttest: $p = 0.044$) showed that three of the four datasets were normally distributed ($p > 0.05$), but the control class's posttest scores were not ($p = 0.044$), and Levene's homogeneity test comparing each class's own pretest and posttest variances showed that variances in both the experimental, $F(1,78) = 1.35$, $p = 0.249$ and control, $F(1,78) = 2.10$, $p = 0.151$, groups were homogeneous ($p > 0.05$). Because the control group's posttest departed from normality, the assumptions for a parametric paired-samples test was not strictly met for that group; the paired t-test is nonetheless reported below, as it is reasonably robust to this degree of non-normality at $n = 40$ (Field, 2018; Sugiyono, 2014). For the between-group (independent) comparison at posttest, the Shapiro-Wilk test indicated that the experimental class's posttest scores were normally distributed ($p = 0.641$) but the control class's were not ($p = 0.044$), while Levene's test indicated the two group's variances were homogeneous, $F(1,78) = 1.71$, $p = 0.195$; because the normality assumption was not met for both groups, the between-group comparison was analyzed with the nonparametric Mann-Whitney U test instead of the Independent Samples T-Test.

A paired-samples t-test examined the pre-post difference in learning interest within each group. For both the experimental class ($df = 39$) and the control class ($df = 39$), the significance value was $p < 0.001$, so H0 was rejected in both cases, confirming a statistically significant pre-post increase in learning interest within each group. However, the magnitude of that increase differed: the experimental class's mean score rose by 42.09 points (from 51.00 to 93.09) compared with 26.12 points for the control class (from 51.53 to 77.64), indicating that the website-based flipped classroom produced a substantially larger gain than conventional instruction, even though both changes were statistically significant. Using the complete set of individual difference scores, the within-group effect size was Cohen's $d_z = 7.53$ for the experimental class and $d_z = 3.55$ for the

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control class; both values are far beyond the conventional “large effect” threshold of 0.80 (Cohen, 1988). Effect sizes of this magnitude are unusually large for a self-report affective measure and should be interpreted cautiously rather than as a straightforward measure of the intervention's power; this is discussed further as a limitation later in this section. This is consistent with Hew et al. (2018), who found that the flipped classroom tends to reduce learning-outcome disparities because students can access learning materials flexibly, and with Darmawati et al. (2023) and Rusman (2012), who report that technology use in learning increases active participation and learning interest.

A Mann-Whitney U test examined the between-group difference in posttest learning interest, since the normality assumptions for the Independent Samples T-Test were not met for both groups. Run directly in SPSS on the 40 experimental and 40 control posttest scores, the test yielded $U = 20.00$, Wilcoxon $W = 840.00$, $Z = –7.509$, and $p < 0.001$ (two-tailed), so H0 was rejected: there was a statistically significant difference in posttest learning interest between the experimental and control classes, in favor of the experimental class. This finding is consistent with Setyadi et al. (2017), who argue that integrating technology into innovative learning models is central to building an interactive, flexible, student-centered environment that increases engagement and motivation.

Analysis of the Increase in Students' Interest in Learning

An analysis of the increase in learning interest was conducted using N-Gain scores to evaluate the effectiveness of the instruction. The results of the statistical analysis are presented in Table 8.

Table 8.

Results of the comparison of the mean and N-Gain scores for interest in learning among students in the experimental and control groups

Description	Experiment (pre)	Experiment (post)	Control (pre)	Control (post)
Maximum Score	100	100	100	100
Minimum Score	20	20	20	20
Highest Score	63.5	100	66	91
Lowest Score	41	84.50	39.50	70.5
Average	51.00	93.09	51.53	77.64
Standard Deviation	4.60	3.69	6.18	4.85
N-Gain Score	0.86		0.54	
N-Gain Percentage	86%		54%	
Criteria	High		Medium	
Percentage Increase	61.38%		38.62%	

The experimental class's N-Gain score (0.86, High, Effective) was 0.32 points higher than the control class's (0.54, Medium, Less Effective), and this gap is corroborated by the significant paired and between-group test results reported above; it is not, therefore, an isolated descriptive difference but one consistent with the inferential statistics. Interpreted as a percentage of the maximum possible gain (Table 7; Sugiyono, 2013), the experimental group's N-Gain of 0.86 corresponds to 86%, in the Effective category, while the control group's N-Gain of 0.54 corresponds to 54%, in the Less Effective category; this is a distinct measure from the “Percentage Increase” row above, which instead expresses each group's N-Gain score as its proportional share of the two groups' combined N-Gain (0.86 + 0.54 = 1.40, i.e., 61.38% and 38.62%).

To express the strength of the between-group difference in a standardized, sample-size-independent metric, an effect size was computed from each participant’s gain score (posttest minus pretest) rather than from posttest score alone: a posttest only comparison would conflate

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the treatment effect with the small baseline difference between the two non-randomized classes, so the gain-score comparison is the more defensible index of effectiveness for this quasi-experimental, non-equivalent-groups design. The experimental class's mean gain (42.09 points, SD = 5.59) exceeded the control class's mean gain (26.12 points, SD = 7.37) by 15.97 points; the between-group Cohen's d on these gain scores was 2.44, and applying the small-sample correction appropriate for n = 40 per group (Hedges & Olkin, 1985) gives Hedges' g = 2.42, 95% CI [1.84, 3.00] – an effect far above the conventional "large" threshold of 0.80 (Cohen, 1988). Expressed instead as a proportion-of-variance effect size, the same gain-score comparison (independent-samples $t(78) = 10.92$, $p < .001$) corresponds to a partial eta squared of $\eta^2p = t^2 / (t^2 + df) = 119.28 / (119.28 + 78) \approx 0.60$; by Cohen's (1988) benchmarks for η^2p (0.01 small, 0.06 medium, 0.14 large), this is also a large effect, meaning group membership (experimental vs. control) accounted for roughly 60% of the variance in learning-interest gain scores, consistent with the Hedges' g estimate above.

This gain-score-based effect size is reported in place of a posttest-only Cohen's d, which would inflate the apparent group difference by not accounting for each class's own starting point. Reporting a standardized effect size alongside the N-Gain score is consistent with recent practice by Firdaus et al. (2025), for instance, reported both a t-test result and a Cohen's d of 0.87 when evaluating a cognitive-outcome intervention in the same journal, and equivalent reporting strengthens the comparability of this study's claims with the wider literature. The finding that the flipped classroom website outperformed conventional instruction is consistent with Mustakim (2020), who found that flipped classroom-based e-learning significantly and effectively increases motivation and interest in high school science subjects, and with Zheng et al. (2020), whose meta-analysis found a moderate-to-high effect of the flipped classroom on learning achievement and motivation.

Discussion

The most direct explanation for the experimental class's larger gain lies in how the website structured students' time: it let them study respiratory system material independently, before and after class, while face-to-face time was reserved for discussion, problem-solving, and deeper exploration of concepts already introduced through the pre-class video material. This interpretation is consistent with Al-Samarraie et al. (2020), who found that the flipped classroom in higher education consistently fosters engagement, metacognitive skills, and academic performance by using class time more productively for concept development, and with Chang et al. (2023), who found that flipped teaching increases learning interest by providing flexible, varied access to content before face-to-face sessions. Oudbier et al. (2022) identify six success factors for flipped classroom implementation: student characteristics, teacher characteristics, implementation quality, task characteristics, out-of-class activities, and in-class activities; in this study, these six factors were addressed through the website's tutorial and concept-representation videos on the respiratory system, interactive quizzes, and structured text material, all accessible at any time, which aligns with the principle of self-paced learning described in the Methods section.

Beyond the overall N-Gain result, the instrument's attention aspect specifically (the second of the three aspects measured, as described in the Instruments subsection) recorded an N-Gain of 0.86 in the experimental class, indicating that the website's structured, systematically organized content helped focus students' cognitive attention during the pre-class and in-class stages. This aspect-level result is consistent with Juliyanti et al. (2022), who found that website-based media for the human sensory system effectively improved high school students' conceptual understanding and elicited positive responses. Repeated, independent access to material provides flexibility that supports diverse learning styles. Divjak et al. (2022) similarly found, in a study of flipped classroom implementation during the COVID-19 pandemic, that web-based technology was central to maintaining student engagement, and that an intuitive platform design and well-structured content were key success factors, consistent with the simple navigation, visual consistency, and immediate quiz feedback built into this study's website design.

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These results are also consistent with the physiology-education literature specifically: Tune et al. (2013) found that graduate students in a flipped classroom achieved significantly higher scores on cardiovascular, respiratory, and renal physiology assessments than students in a conventional lecture group, and Ridlo et al. (2022), studying a virtual, science-literacy-based flipped classroom at three Indonesian high schools, found the model effective in enhancing students' positive attitudes, self-efficacy, and self-regulation in biology learning. Although these studies differ in educational level and specific topic, they show a pattern consistent with the present study: flipped classrooms consistently yield greater affective and cognitive gains than conventional instruction in biology and physiology education.

This pattern also holds across other recent digital-media interventions on human organ-system topics published in the same journal. Harahap et al. (2025) found that an interactive animation-based flipbook produced a substantially higher N-Gain (0.72) on the human digestive system than conventional instruction (0.29). Firdaus et al. (2025) reported a large effect (Cohen's d = 0.87) of a Kahoot- and e-poster-assisted model on cognitive outcomes for the excretory system. Fitriyana et al. (2025) found that flipbook-assisted discovery learning improved outcomes on plant taxonomy material beyond conventional instruction. Mauludin et al. (2025) found that an augmented-reality e-module significantly improved conceptual understanding and learning independence on virus material. Taken together with the present study's results on the respiratory system, this converging evidence suggests that structured, technology-based media consistently outperform conventional instruction across a range of biology topics traditionally considered abstract and difficult, rather than the respiratory system being a special case.

Two conditions nonetheless qualify this study's findings and should guide broader implementation. First, students' technological readiness and the availability of digital infrastructure are prerequisites for a website-based flipped classroom to work as intended, at any education level (Al-Samarraie et al., 2020). This study's field trial took place in a single school with adequate internet access, so its results should not be generalized without first confirming comparable infrastructure elsewhere. Second, the flipped classroom's effectiveness for respiratory system material does not lie in the technology alone but in how class time is repurposed for more meaningful teacher-student interaction (Lin et al., 2023; Wei, 2021), then a website without a correspondingly redesigned in-class routine, such as the discussion and problem-solving activities implemented here, would not be expected to reproduce these results. Third, the within-and between- group effect sizes reported above (Cohen's dz up to 7.53; Hedges' g = 2.42) are far larger than is typical for affective, self-report outcomes in educational research, which more commonly fall in the small-to-moderate range; this pattern most plausibly reflects the combination of a developer-created instrument administered by the same team that built the website, no blinding of students or raters to condition, and measurement immediately after a novel intervention, any of which can inflate self-reported interest independently of a genuine underlying change, rather than reflecting a uniquely powerful treatment effect; independent replication with a previously validated instrument and, ideally, a behavioral or blinded measure of interest would strengthen confidence in the size, though not necessarily the direction, of this effect.

CONCLUSION

This study met both of its stated objectives. First, a flipped classroom-based website for human respiratory system material was developed following the ADDIE model and validated by media, subject-matter, and practitioner experts before field testing. Second, the field trial showed that this website-based flipped classroom instruction was effective in increasing eleventh-grade students' learning interest in the respiratory system: the experimental class achieved an N-Gain score of 0.86 (High, Effective), against 0.54 (Medium, Less Effective) for the conventionally taught

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control class, a difference corroborated by significant paired and between-group hypothesis tests. This study therefore provides empirical, statistically supported evidence, from a single-school field trial, that integrating digital technology into biology instruction through a website-based flipped classroom model can measurably increase learning interest compared with conventional instruction, for material of high conceptual complexity such as the respiratory system. Wider adoption should be preceded by replication in schools with varying levels of digital infrastructure and teacher readiness, and by studies that also measure conceptual understanding, since this study assessed learning interest only.

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Authors' Note

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