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Developing a Simulation-Embedded E-Module for Projectile Motion Using Google Sites: An ADDIE-Based Study on Physics Learning Effectiveness

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ABSTRACT

Projectile motion is a conceptually challenging topic because students must coordinate vector decomposition, kinematic reasoning, and multiple representations. Although simulations and e-modules have been widely adopted in physics education, evidence remains limited regarding teacher-maintainable, web-based modules that integrate simulations within a structured instructional framework. This study aimed to develop and evaluate a simulation-embedded e-module for projectile motion using Google Sites and the ADDIE instructional design model. A research and development approach was employed following the ADDIE stages: Analyze, Design, Develop, Implement, and Evaluate. The product was validated by three experts in physics content, instructional design, and language. Practicality was assessed through questionnaires administered to 36 students and one physics teacher. Effectiveness was examined using a quasi-experimental pretest-posttest control-group design involving 72 senior high school students, with 36 students in the treatment group and 36 in the control group. Expert evaluation indicated that the e-module achieved a very high level of validity (M = 3.68/4.00). Student practicality ratings were also very high (M = 3.57/4.00), while teacher evaluation confirmed strong classroom feasibility (M = 3.75/4.00). The treatment group demonstrated significantly higher posttest achievement and normalized gain than the control group ($p < .01$), with moderate-to-large effect sizes (Hedges' g = 0.68–0.79). The findings suggest that integrating simulations within a structured Google Sites e-module can enhance conceptual understanding of projectile motion by supporting guided inquiry, multi-representational learning, and immediate visual feedback. The study highlights the potential of Google Sites as an accessible, low-code platform for scalable and teacher-maintainable physics learning resources.

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1. INTRODUCTION

Projectile motion is one of the fundamental topics in secondary school physics because it integrates several core concepts, including vector decomposition, two-dimensional kinematics, and the interpretation of graphical and mathematical representations. To achieve a meaningful understanding of projectile motion, students must recognize that horizontal and vertical motions occur simultaneously but independently, with horizontal motion characterized by constant velocity and vertical motion influenced by gravitational acceleration. In addition, learners are expected to translate among equations, graphs, diagrams, and trajectory representations to develop coherent conceptual models rather than relying solely on procedural problem-solving techniques (Ainsworth, 2006; Tabor-Morris, 2020). Mastery of these concepts is essential because projectile motion serves as a foundation for more advanced topics in mechanics and supports scientific reasoning across various physical phenomena.

Despite its importance, projectile motion remains a challenging topic for many students. Previous studies have reported persistent misconceptions related to the independence of horizontal and vertical motion, the role of gravitational acceleration, and the interpretation of velocity and displacement throughout a projectile's trajectory (Fongsamut et al., 2022; Hidayatulloh et al., 2021; Uwayezu & Yadav, 2023). Students frequently struggle to connect mathematical equations with the physical meaning of motion, leading to fragmented understanding and difficulties in transferring knowledge to unfamiliar situations. Traditional instructional approaches that rely heavily on textbook explanations, static diagrams, and worked examples often provide limited opportunities for learners to visualize dynamic changes in motion variables such as launch angle, initial velocity, and flight time (Shah et al., 2018; Tabor-Morris, 2020). Consequently, students may successfully solve routine computational problems while still lacking a deep conceptual understanding of the underlying physics principles.

To address these challenges, educational researchers have increasingly emphasized the use of interactive technologies that promote active learning and conceptual visualization. Among these technologies, computer simulations have shown considerable potential in improving students' understanding of abstract scientific concepts. Simulations enable learners to manipulate variables, observe immediate changes in motion trajectories, and compare visual outcomes with theoretical predictions, thereby supporting inquiry-based learning and conceptual change (Fongsamut et al., 2022; Uwayezu & Yadav, 2023). Research reviews have consistently demonstrated that simulation-based learning can enhance conceptual understanding, particularly when simulations are integrated with instructional guidance and opportunities for reflection rather than being used as standalone visualization tools (Rutten et al., 2012; Smetana & Bell, 2012; Wieman et al., 2008). Through prediction, observation, and explanation activities, students can actively test their ideas, confront misconceptions, and develop stronger connections among symbolic, graphical, and visual representations of physical phenomena.

In parallel with advances in simulation technology, digital learning modules have emerged as effective tools for supporting self-directed and flexible learning. E-modules allow students to access instructional materials at their own pace, revisit difficult concepts, and receive formative feedback during the learning process (Cruz & Bustoba, 2022; Delita et al., 2022; Fadieny & Fauzi, 2021). Previous studies have shown that well-designed e-modules can improve learning motivation, self-efficacy, and academic achievement by facilitating active engagement with content (Aladin et al., 2024). However, many existing digital resources remain fragmented. In some cases, simulations are provided separately from instructional materials, requiring students to switch between multiple platforms and potentially disrupting cognitive continuity during learning. In other cases, digital modules function primarily as static electronic documents with limited interactivity and restricted opportunities for inquiry-based exploration (Azizahwati et al., 2023; Basagre et al., 2022).

Recent developments in web-based technologies provide opportunities to overcome these limitations through integrated learning environments. Google Sites offers a low-code platform that enables teachers to create, update, and distribute digital learning materials through a single web link without requiring advanced programming skills. The platform supports multimedia integration, crossdevice accessibility, and flexible content management, making it a practical solution for classroom implementation (Grünigen et al., 2021; Jung & Huh, 2019). By embedding simulations directly within structured learning sequences, Google Sites can facilitate seamless transitions between conceptual explanations, inquiry activities, practice exercises, and reflective tasks. Such integration may reduce cognitive load associated with navigating multiple platforms while enhancing learner engagement and conceptual understanding.

Although studies have examined the effectiveness of simulations and e-modules separately, empirical evidence remains limited regarding simulation-embedded, teacher-maintainable e-modules hosted on freely accessible web platforms. Furthermore, relatively few studies have investigated how such integrated learning environments can support multi-representational understanding of projectile motion while remaining practical for classroom adoption. This gap highlights the need for instructional innovations that combine simulation technology, structured pedagogical design, and accessible web-based delivery systems. Therefore, this study developed a simulation-embedded e-module for projectile motion using Google Sites and the ADDIE instructional design model. The module was designed to promote mindful, meaningful, and joyful learning through guided inquiry activities, interactive simulations, formative assessments, and reflective prompts. Specifically, this study sought to answer the following research questions: (1) How valid is the simulation-embedded Google Sites e-module based on expert evaluation? (2) How practical is the e-module for teachers and students in a senior high school physics context? and (3) Does the e-module improve students' learning outcomes more effectively than conventional instructional resources? By addressing these questions, the study contributes to the growing body of research on scalable and teacher-maintainable digital learning innovations in physics education.

2. METHODS

2.1 Research Design

This study employed a research and development approach using the ADDIE model--Analyze, Design, Develop, Implement, and Evaluate--to produce and evaluate a simulation-embedded e-module on projectile motion (Halim et al., 2019; Patel et al., 2018). The product evaluation focused on three dimensions commonly used in educational development studies: validity, practicality, and effectiveness (Halim et al., 2019; Rahman et al., 2025).

To examine learning effectiveness, the implementation stage used a quasi-experimental pretest-posttest control-group design. This design was appropriate because the study was conducted in a natural school setting where students were already organized into intact classes and random assignment was not feasible. Therefore, the treatment and control groups were not randomly formed. To reduce this limitation, both groups completed the same pretest before instruction, studied the same curricular topic during the same instructional period, and were compared for baseline equivalence before posttest outcomes were interpreted. Because of the non-random assignment, the findings should be interpreted as evidence of classroom effectiveness rather than as a fully randomized causal estimate.

Table 1. Research Design, Evaluation Dimensions, and Data Sources

Evaluation dimension	Design/approach	Data source	Participants	Output reported
Validity	Expert judgment during design/development review	Validation rubric	3 validators representing content, media/design, and language/readability expertise	Mean scores by aspect and validity category
Practicality	Field try-out during implementation	Student and teacher	36 students in the treatment class and 1 physics teacher	Item means, overall mean, category, and reliability for student questionnaire

Evaluation dimension	Design/approach	Data source	Participants	Output reported
		practicality questionnaires		
Effectiveness	Quasi-experimental pretest-posttest comparison	Projectile motion learning test	72 students: 36 treatment and 36 control	Mean, standard deviation, mastery rate, normalized gain, significance tests, and effect sizes

2.2 Participants and Context

The study was conducted in an urban senior high school physics setting in Surabaya, Indonesia, during the mechanics unit on two-dimensional motion. The participants were selected through convenience sampling because the study used available intact classes assigned by the school. A total of 72 students participated: 36 students in the treatment class and 36 students in the control class. The treatment class learned using the simulation-embedded Google Sites e-module, while the control class learned using conventional resources commonly used at the school, such as teacher explanation, textbook-based activities, and worksheet practice. One physics teacher supported implementation and completed the teacher practicality questionnaire.

Expert validation involved three validators with complementary expertise: physics content, instructional/media design, and language/readability. This composition ensured that the e-module was reviewed for scientific accuracy, instructional quality, interface clarity, and readability, consistent with R&D validation practices in educational technology development (Rahman et al., 2025).

2.3 Product Description and Development Procedure (ADDIE)

The developed product was a web-based e-module hosted on Google Sites and accessible through a single URL. The module integrated concept explanations, guided inquiry activities, an embedded interactive simulation, formative checks, and reflection prompts aligned with mindful, meaningful, and joyful learning principles (Mamun, 2022; Parker et al., 2022; Vaičiūnienė & Kazlauskienė, 2023). The final site map is presented in Fig. 2.

The ADDIE procedure was implemented as follows. In the Analyze stage, needs analysis was conducted through teacher consultation and literature review on student difficulties in projectile motion. Key problems included misconceptions about the independence of horizontal and vertical motion and difficulty translating among equations, graphs, diagrams, and trajectories (Fongsamut et al., 2022; Hidayatulloh et al., 2021; Uwayezu & Yadav, 2023). Platform constraints, including accessibility, device compatibility, and ease of updating, informed the selection of Google Sites as a no-code delivery platform (Jung & Huh, 2019; Ma et al., 2017).

In the Design stage, learning objectives were specified for conceptual understanding and multi-representation translation. Activities were organized into guided inquiry sequences using predict-observe-explain prompts. Mindful learning was operationalized through attention-control prompts and reflection checkpoints; meaningful learning was supported through tasks connecting simulation outputs with symbolic and graphical representations; and joyful learning was supported through interactive what-if challenges and immediate visual feedback (Mamun, 2022; Parker et al., 2022; Vaičiūnienė & Kazlauskienė, 2023).

In the Develop stage, the module pages were built in Google Sites with consistent navigation, typography, and visual layout. The projectile motion simulation was embedded directly into activity pages to reduce context switching and maintain continuity between explanation, exploration, and assessment (D. S. Suherman, 2025; Uwayezu & Yadav, 2023). Draft I was then submitted for expert validation. In the implementation stage, the revised module was piloted in the treatment class during regular instruction, while the control class used conventional school resources. In the Evaluate stage, expert validation, practicality testing, and learning effectiveness analysis were used to determine product quality and learning impact.

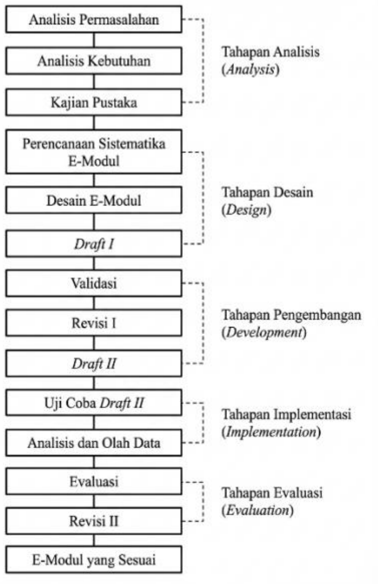

Figure 1. ADDIE Development Flow

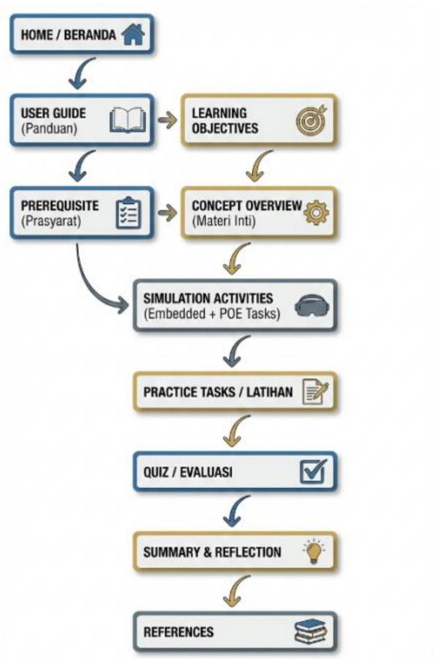

Figure 2. Site Map/Structure of the Google Sites E-Module

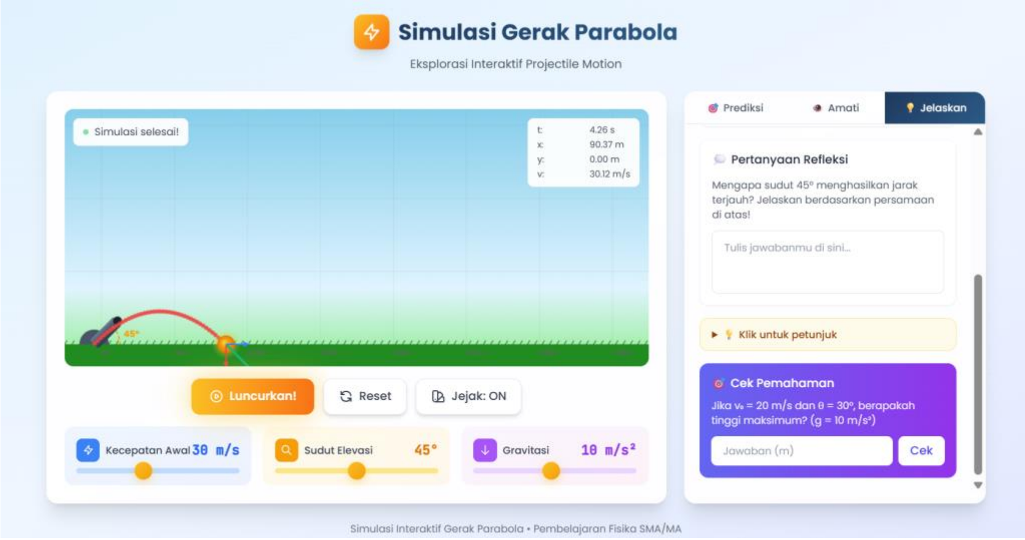

Figure 3. Representative Screenshots of the Module Interface and the Embedded Simulation with POE Prompts

2.4 Instruments

Four instruments were used: an expert validation rubric, a student practicality questionnaire, a teacher practicality questionnaire, and a projectile motion learning test.

Table 2. Instruments, Constructs, Scoring, and Interpretation

Instrument	Construct(s) measured	Items/format	Scale/scoring	Interpretation
Expert validation rubric	Content accuracy, instructional design, simulation integration, interface/navigation, and language clarity	5 aspects with 4 items per aspect	1-4 scale: 1 = poor, 4 = excellent	Higher mean indicates stronger validity
Student practicality questionnaire	Access, navigation, instruction clarity, visual comfort, simulation usefulness, motivation, efficiency, and satisfaction	8 Likert items	1-4 scale: strongly disagree to strongly agree	Higher mean indicates greater practicality
Teacher practicality questionnaire	Feasibility, classroom usability, time efficiency, integration quality, and assessment suitability	8 Likert items	1-4 scale	Higher mean indicates greater classroom feasibility
Learning test	Conceptual understanding and problem solving on projectile motion	Objective items aligned with indicators	Raw score converted to 0-100	Used for pretest, posttest, normalized gain, mastery, and group comparison

To strengthen validity evidence, the learning test was developed from an indicator blueprint, reviewed for content alignment, and administered in the same format to both groups. Each objective item was scored as correct or incorrect, and the total score was converted to a 0-100 scale. The mastery criterion was set at a posttest score of 75 or higher, following the school's minimum mastery standard.

Table 3. Mean Score Categories for Validation and Practicality Instruments

Mean range	Category used in reporting
3.50-4.00	Very valid / Very practical
3.00-3.49	Valid with minor revision / Practical
2.00-2.99	Needs revision
1.00-1.99	Not acceptable

Table 4. Blueprint of the Projectile Motion Learning Test

Learning Indicator	Conceptual Focus	Example Item Focus	Scoring Procedure
Identify horizontal and vertical components of projectile motion	Vector decomposition and independence of components	Students determine horizontal and vertical velocity components from initial speed and launch angle	Correct = 1; incorrect = 0
Explain acceleration and velocity changes during flight	Gravitational acceleration and velocity direction	Students identify acceleration at the highest point and explain vertical velocity changes	Correct = 1; incorrect = 0
Interpret trajectory, graph, and equation relationships	Multi-representation translation	Students match a trajectory with the corresponding position-time or velocity-time graph	Correct = 1; incorrect = 0
Solve projectile motion problems	Range, maximum height, and time of flight	Students calculate one projectile quantity using given initial conditions	Correct = 1; incorrect = 0

For the student practicality questionnaire, items P1-P8 represented ease of access, navigation clarity, instruction clarity, visual comfort, simulation contribution, motivation/interest, learning efficiency, and overall satisfaction. These constructs were aligned with usability and learning-experience indicators commonly used in digital module evaluation (Cruz & Bustoba, 2022; Rahman et al., 2025).

2.5 Data Collection Procedure

Data were collected in three phases. First, Draft I of the e-module was reviewed by the three validators. Validators completed the rubric and provided qualitative comments that informed product revision. Second, the revised module was implemented in the treatment class. After using the module, students completed the practicality questionnaire, and the teacher completed the teacher practicality questionnaire. Third, both treatment and control classes completed a pretest before instruction and a posttest after instruction. All instruments were administered under classroom-supervised conditions to reduce missing responses and ensure comparable testing procedures.

2.6 Data Analysis

Data were analyzed using IBM SPSS Statistics software. Validity was analyzed by calculating the mean score for each validation aspect and the overall mean across aspects. Practicality was analyzed using item means and overall means for student and teacher questionnaires. The reliability of the student practicality questionnaire was examined using Cronbach's alpha. Teacher practicality was reported descriptively because there was only one teacher respondent.

Learning effectiveness was analyzed using pretest and posttest means, standard deviations, mastery rate, and normalized gain. Between-group comparisons were conducted at a significance level of alpha = .05. Normality and homogeneity assumptions were checked before inferential testing. Welch's t-test was used when the assumption of equal variances was not met. Effect sizes were reported to support the interpretation of practical significance in addition to p-values (Eleo & Manguilimotan, 2024).

2.7 Trustworthiness, Validity Controls, and Ethical Considerations

Several procedures were used to strengthen trustworthiness. Content alignment was established by linking learning objectives, module activities, and assessment indicators during the design phase. Expert validation was used to review content accuracy, instructional design, simulation integration, interface quality, and language clarity. During implementation, both groups studied the same curriculum topic within the same instructional period and completed equivalent pretest and posttest measures.

Ethical procedures followed standard educational research practices. Permission was obtained from the school administration and the participating teacher before data collection. Students were informed about the purpose of the study, the voluntary nature of participation, and the use of anonymized data for research reporting. Student identities were replaced with codes, and results were reported only at the group level. The teacher and validators provided consent for their participation and for the use of their feedback in product revision reporting.

3. FINDINGS AND DISCUSSION

3.1 Product Development Results

The study produced a simulation-embedded, Google Sites-based e-module for projectile motion using the ADDIE model. The final product was designed as a single web link that students could access through smartphones, tablets, or laptops. The module contained learning objectives, user guidance, prerequisite review, core concept explanations, embedded simulation, guided inquiry activities, practice tasks, formative quizzes, and reflection prompts. These components were arranged to support mindful, meaningful, and joyful physics learning.

The module emphasized the independence of horizontal and vertical motion, the relationship between launch parameters and trajectory shape, and translation among equations, graphs, and visual motion representations. The embedded simulation was placed directly within the learning sequence so that students did not need to move between separate platforms during inquiry activities.

3.2 Validity Findings

Expert validation showed that the e-module met the criteria for classroom implementation. The strongest aspect was simulation integration, while interface and navigation received the lowest mean score and therefore became the main focus for revision.

Table 5. Expert Validation of the Simulation-Embedded E-Module

Aspect	Mean	Category
Content	3.75	Very valid
Instructional design	3.67	Very valid
Simulation integration	4.00	Very valid
Interface and navigation	3.42	Valid with minor revision
Language clarity	3.58	Very valid
Overall	3.68	Very valid

The overall validity score indicated that the module had accurate content, appropriate instructional organization, and effective simulation integration. The relatively lower score for interface and navigation suggested the need for clearer menu labels, more consistent page flow, improved readability, and reduced screen density.

3.3 Practicality Findings

Practicality was evaluated from student and teacher perspectives. The student questionnaire showed that the module was very practical overall. Students rated motivation/interest and navigation clarity highly, indicating that the Google Sites structure and simulation-based activities supported both engagement and usability.

Table 6. Student Practicality of the Google Sites E-Module

Item	Mean	Category
P1: Ease of access	3.56	Very practical
P2: Navigation clarity	3.64	Very practical
P3: Instruction clarity	3.61	Very practical
P4: Visual comfort/attractiveness	3.44	Practical
P5: Simulation helps understanding	3.61	Very practical
P6: Motivation/interest	3.69	Very practical
P7: Learning efficiency	3.44	Practical
P8: Overall satisfaction	3.56	Very practical
Overall	3.57	Very practical

The internal consistency of the student practicality questionnaire was acceptable, with Cronbach's alpha of .81. The two lowest student-rated aspects were visual comfort and learning efficiency. This finding aligned with the expert review and indicated that future revision should focus on reducing scrolling, simplifying page layout, improving spacing, and optimizing loading performance.

Table 7. Teacher Practicality of the Google Sites E-Module

Item	Score
P1	4
P2	4
P3	4
P4	3
P5	4
P6	4
P7	3
P8	4
Overall	3.75

The teacher also rated the e-module as very practical. The lower scores on P4 and P7 were consistent with student feedback, confirming that visual comfort and time efficiency were the main aspects requiring refinement.

3.4 Effectiveness Findings

The effectiveness test showed that both groups improved from pretest to posttest, but the treatment group achieved stronger learning outcomes. The treatment group had a higher posttest mean, higher mastery rate, and higher normalized gain than the control group.

Table 8. Learning Outcomes by Group

Group	n	Pretest Mean ± SD	Posttest Mean ± SD	N-gain Mean ± SD	Mastery: Posttest ≥ 75
Treatment: e-module	36	42.06 ± 12.07	75.54 ± 13.58	0.59 ± 0.19	66.67%
Control: conventional resources	36	40.49 ± 11.02	67.12 ± 10.77	0.44 ± 0.16	27.78%

Baseline pretest scores did not differ significantly between groups, indicating that the two classes had comparable initial understanding. After instruction, the treatment class achieved significantly higher posttest performance and normalized gain, with moderate-to-large effect sizes.

Table 9. Statistical Testing and Effect Sizes

Comparison	Test	Result	p-value	Effect size
Pretest: Treatment vs Control	Welch's t-test	t(69.43) = 0.57	.568	Hedges' g = 0.13
Treatment: Pretest vs Posttest	Paired t-test	t(35) = 16.15	< .001	d_z = 2.69
Control: Pretest vs Posttest	Paired t-test	t(35) = 12.95	< .001	d_z = 2.16
Posttest: Treatment vs Control	Welch's t-test	t(66.54) = 2.92	.005	Hedges' g = 0.68
N-gain: Treatment vs Control	Welch's t-test	t(68.70) = 3.38	.001	Hedges' g = 0.79

3.5 Interpretation of Findings

The findings suggest that the simulation-embedded Google Sites e-module supported students' conceptual understanding of projectile motion more effectively than conventional resources. Projectile motion requires students to coordinate vector components, acceleration, trajectory shape, and mathematical relationships. The treatment group's stronger posttest and normalized gain results indicate that the module helped students build more integrated understanding of these relationships.

The embedded simulation likely contributed to this improvement by making abstract motion relationships visible. Students could manipulate launch angle and initial speed, observe changes in trajectory, and compare their predictions with simulation outcomes. This process is consistent with international studies and reviews showing that simulations can improve conceptual reasoning when they are paired with guidance, feedback, and opportunities for active sense-making (Fongsamut et al., 2022; Rutten et al., 2012; Smetana & Bell, 2012; Uwayezu & Yadav, 2023; Wieman et al., 2008). The use of guided predict-observe-explain activities also reduced the risk of unguided exploration, which can occur when simulations are used without structured prompts (Basagre et al., 2022; Rivera-Ortega et al., 2023).

The practicality findings indicate that the module was not only effective but also feasible for classroom use. Students' high rating for motivation/interest suggests that interactive exploration and immediate feedback can support joyful learning and persistence in a difficult physics topic. This aligns with studies on game-inspired and interactive learning environments that emphasize engagement, curiosity, and sustained attention in science learning (Herodotou, 2017; Parker et al., 2022; Shah et al., 2018). The reflection prompts and guided inquiry tasks supported mindful learning by encouraging students to monitor their reasoning, while multi-representation tasks supported meaningful learning by connecting equations, diagrams, graphs, and physical interpretation (Ainsworth, 2006; Mamun, 2022; Vaičiūnienė & Kazlauskienė, 2023).

From a development perspective, Google Sites offered practical advantages as a low-code platform. Teachers can update pages, share the module through a single URL, and adapt content without advanced programming skills. This feature addresses common adoption barriers in digital learning, such as cost, installation, maintenance, and device compatibility (Grünigen et al., 2021; Jung & Huh, 2019; Ma et al., 2017). However, the findings should not be overgeneralized to nationwide implementation because the study was limited to one school context and two intact classes. The more appropriate implication is that Google Sites can be a feasible platform for classroom-level digital module development when the module is pedagogically structured and locally adapted.

3.6 Implications and Limitations

The main instructional implication is that simulation-embedded modules are most useful when the simulation is not treated as an isolated tool. Instead, it should be integrated into a sequence of explanation, prediction, observation, discussion, practice, and reflection. This structure helps students move from visual observation to conceptual explanation and problem-solving.

The study has several limitations. First, the use of intact classes' means that random assignment was not possible, so causal claims should be made cautiously. Second, the study was conducted in one school and measured learning immediately after the intervention. Third, the study focused on achievement outcomes and did not include delayed retention tests, misconception diagnostics, or learning analytics. Future studies should involve multiple schools, delayed posttests, richer diagnostic measures, and analysis of student interaction data to clarify how students use simulation-embedded modules during learning.

4. CONCLUSION

This study developed a simulation-embedded e-module for projectile motion using Google Sites and the ADDIE model. The product met high standards of validity and practicality, indicating that the content, instructional design, simulation integration, and classroom usability were appropriate for senior high school physics learning. The quasi-experimental results showed that students who used the e-module achieved better learning outcomes than students who learned through conventional resources. The key takeaway is that simulation-embedded modules can support conceptual physics learning when they are integrated within structured pedagogy. In this study, the combination of guided inquiry, immediate visual feedback, formative checks, and reflection prompts helped students connect equations, graphs, and trajectory behavior in projectile motion. Practically, Google Sites offers a low-code platform that teachers can use to deploy, update, and share interactive learning materials through a single web link.

Future research should test the module in broader school contexts, examine retention through delayed posttests, and include misconception diagnostics or learning analytics to identify how students interact with simulation-based tasks. Further product refinement should focus on visual comfort, page efficiency, loading performance, and navigation flow.

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