

Validation of STATIC: An Integrated Digital Learning Platform for Electrostatics

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ARTICLE INFO	ABSTRACT
Keywords: Artificial Intelligence; Augmented Reality; Integration; PhET; Technology	Advances in digital technology have significantly transformed the educational landscape. However, electrostatics remains one of the most challenging topics for junior high school students because its concepts are abstract, while laboratory activities are often limited by inadequate facilities and instructional time, particularly in schools in the Ponorogo region. Therefore, this study aims to develop and validate STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics), an integrated digital learning platform designed to support electrostatics learning. This study employed a three-stage Research and Development (R&D) model consisting of Define, Design, and Develop. Product validation was conducted by three junior high school science teachers using a five-point Likert-scale instrument that assessed content relevance, accessibility, practicality, ease of understanding, aesthetics, and efficiency. The validation results showed an overall score of 92%, categorized as Highly Recommended, indicating that STATIC is valid and suitable for use as a digital learning platform. These findings suggest that STATIC has the potential to support electrostatics learning by providing an integrated platform that combines learning materials, Augmented Reality (AR), PhET simulations, educational games, interactive quizzes, and Artificial Intelligence (AI), particularly in schools with limited laboratory facilities.
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INTRODUCTION

The rapid development of educational technology has transformed learning into a more interactive and meaningful process. Interactive learning media that integrate multimedia, simulations, and digital features can enhance learning effectiveness, engagement, and student participation (Suhenda et al., 2024). In physics education specifically, digital technology helps students understand abstract concepts by connecting them with real-world phenomena (Lumbantoruan et al., 2025), and instructional media play an essential role in facilitating concept delivery and improving students' understanding, particularly in science learning that emphasizes both conceptual mastery and scientific process skills (Meila Intantri et al., 2025). Among the topics in physics education, static electricity remains particularly difficult to learn because its phenomena are abstract and not directly observable (Fatimah & Bramastia, 2021). This creates a pedagogical problem, students struggle to build accurate mental models of electrostatic concepts without concrete, visualizable representations.

Previous studies have offered several technological solutions to address this problem. Augmented Reality (AR) has been shown to improve student engagement and learning outcomes (Bakri et al., 2025); PhET Interactive Simulation enhances conceptual understanding, critical thinking, and learning engagement specifically in static electricity topics (Apriyani et al., 2026); while Artificial Intelligence (AI) supports personalized learning, adaptive assessment, and rapid feedback (Almasri, 2024; Cooper & Tang, 2024; Zhang et al., 2024). Each technology therefore addresses a different dimension of the learning process AR for visualization, PhET for virtual exploration, and AI for personalization. However, despite their individually proven benefits, these technologies are generally developed and implemented separately, resulting in a technological problem, no existing platform integrates visualization, simulation, and adaptive personalization within a single, cohesive learning experience for static electricity.

To address these two problems, this study developed STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics), a digital learning platform that integrates AR, PhET Interactive Simulation, AI, educational games, and interactive quizzes. Unlike existing standalone applications that often require specific hardware or software environments, STATIC is designed to be accessible across various devices, providing a more concrete, interactive, and engaging learning experience while serving as an alternative to laboratory activities that are often constrained by limited facilities, equipment, and instructional time.

This study aims to develop and evaluate the validity, practicality, and effectiveness of STATIC in improving students' understanding of static electricity and learning engagement. The novelty of STATIC lies in its integration of visualization, virtual exploration, interactive assessment, and personalized learning within a single, device flexible platform an integration that, to the researchers' knowledge, has not been addressed in prior studies on static electricity instruction.

RESEARCH METHOD

This study employed the Research and Development (R&D) approach using Thiagarajan's 4-D model (Define, Design, Develop, and Disseminate). Owing to the scope of the study, the development process was conducted only through the Develop stage, which was limited to expert validation of the developed prototype (Budi Indaryanti et al., 2025).

The product developed was STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics), a digital learning platform for electrostatics instruction that integrates Augmented Reality (AR), PhET Interactive Simulations, Artificial Intelligence (AI), educational games, and interactive quizzes. The development process included three stages. During the Define stage, curriculum requirements, learner characteristics, electrostatics concepts, and existing instructional media were analyzed to identify learning needs. The Design stage involved preparing the learning content, designing the user interface and navigation, and developing the initial prototype. The Develop stage focuses on expert validation of the prototype to evaluate its feasibility.

The product was validated by subject-matter experts, media experts, and physics teachers using a structured validation questionnaire on a five-point Likert scale. The instrument evaluated several aspects of the media, including content quality, language, presentation, technical quality, interactivity, and usability.

The validation data were analyzed using descriptive quantitative analysis by converting the obtained scores into percentages. The feasibility of the developed media was interpreted using the criteria presented in Table 1.

Table 1. Media Feasibility Criteria

Score	Criteria
81% – 100%	Highly Recommended
61% – 80%	Appropriate

41% – 60%	Quite Decent
21% – 40%	Not Suitable
≤ 20%	Unsuitable

The percentage of media feasibility was calculated using the following equation:

$$\text{Feasibility Percentage} = \frac{\text{Total Score Obtained}}{\text{Maximum Possible Score}} \times 100\%$$

The resulting percentage was then interpreted according to the criteria shown in Table 1 to determine the feasibility level of the STATIC learning platform.

RESULT AND DISCUSSION

Define

The define stage in this study plays a crucial role as the initial foundation for designing instructional media that aligns with the learning needs of electrostatics. The results of the analysis indicate that electrostatics is an abstract concept that is difficult for students to understand because it cannot be directly observed. This condition is consistent with previous findings stating that invisible physics concepts tend to lead to misconceptions if they are not supported by adequate visualization (Resbiantoro et al., 2022).

From a curriculum perspective, the analysis shows that electrostatics requires students not only to understand concepts theoretically but also to relate them to real-life phenomena. However, in practice, limitations in laboratory facilities and instructional time allocation hinder the optimal implementation of experimental activities. This situation results in a lack of direct learning experiences, which are essential components of concept-based science learning (Remperas & Calzada, 2025).

The analysis of student characteristics reveals that students at the junior secondary level (SMP/MTs) tend to understand learning materials more effectively through visual, interactive, and technology-based approaches. Additionally, students demonstrate a high level of interest in digital learning media that enable independent exploration and provide immediate feedback. Therefore, the use of technologies such as Augmented Reality (AR), interactive simulations, and Artificial Intelligence (AI) is considered relevant to bridge the gap between students' learning needs and the abstract nature of the subject matter (Vidak et al., 2023).

Furthermore, the concept analysis identifies several topics in electrostatics that have the potential to cause misconceptions, including electric force interactions, charge distribution, and electrostatic phenomena in daily life. These concepts require dynamic and

simulation-based visualization approaches to be understood more concretely. Therefore, the integration of visual technologies and interactive simulations becomes a critical need to support deeper conceptual understanding.

In addition, the analysis of previously used instructional media indicates that existing media are still partial and not integrated into a comprehensive platform. The use of fragmented media leads to less effective learning processes and fails to provide a holistic learning experience. Moreover, there is still a lack of instructional media that specifically integrates AR, AI, and interactive simulations into a unified system for teaching electrostatics.

Based on the overall findings of the define stage, it can be concluded that there is an urgent need for instructional media capable of integrating multiple technologies into a unified platform. Such media are expected to combine visualization, simulation, interactivity, and adaptability to support more meaningful learning. Therefore, the development of STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics) is proposed as a relevant solution to address these issues while also filling the existing research gap in technology-based instructional media development.

Design

The design phase aims to develop a prototype that includes the creation of a logical, intuitive, and user-friendly structure and navigation layout for the electrostatics learning media through the STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics) application, tailored to the needs of junior high school (SMP/MTs) students and based on the findings from the define phase. The steps taken include selecting the learning medium by establishing application display specifications that are consistent, responsive, and aesthetically pleasing (Dewi et al., 2025). In the digital age, an application with interactive features can serve as a digital learning medium for electrostatics by integrating five technological features: AR (Augmented Reality), PhET Simulation, AI (Artificial Intelligence), Educational Games, and Interactive Quizzes into a single integrated platform. Next, during the content development phase, the application develops renewable energy content based on junior high school/MTs-level teaching materials.

The storyboard design process involves creating the application's interface or layout as a visual blueprint that serves as a technical guide during the media development process to ensure a focused learning flow. A storyboard is a sequence of visual images arranged to

represent the entire flow of the instructional media before the technical development phase begins (Kunto et al., 2021). As a planning document, a storyboard includes descriptions of each scene, content, and interactive elements. The storyboard serves as a conceptual planning tool that conveys ideas and concepts in a creative and structured manner, thereby facilitating the subsequent media development process and influencing the quality of the resulting learning media. The STATIC storyboard used in this study was developed based on Research and Development (R&D) guidelines and instructional design principles, covering the entire flow from the opening screen to the learning outcomes summary page.

Table 4. Storyboard Outline for the STATIC Application Learning Media

no.	Frame	STATIC Feature	Visual & Content Description	Interactive Elements
1		Initial screen	STATIC logo, electrostatic animation (electric sparks), media title, app developer name, start button	Moving electric animation and an automatic button leading to the main menu
2	Opening 	App menu buttons	navigation header, static electricity theme, brief description of the material, motivational quotes, and a navigation grid to all media features. A campus map and developer profile are located at the bottom. There are also menu buttons for (1) Content, AR, (2) PhET Simulations, (3) AI Assistant, (4) Educational	Hover effect on each icon; navigation via click/tap

			Games, (5) Interactive Quizzes, and a footer: Help & Profile	
3	Lesson Materials Page 	Static Electricity	This section covers electric charge, Coulomb's Law, electric fields, and electric potential. It includes interactive illustrations, formulas, and practical examples	Text, illustrations, physics formulas, and a "Next" button
4	AR Features and AI Assistant 	Two standout features (augmented reality and AI)	AR Viewer for 3D visualization of atoms, electric charges, and electric fields using the device's camera, and STATIC AI, an AI-powered chatbot that provides interactive responses	AR camera, barcode scanner, 3D rotation
5	Educational Videos Page 	youtube	Includes video player controls and a brief description below the video. Students can watch an animated visual explanation of static electricity.	Play, pause, and speed
6	Interactive Simulation Page	Phet simulation	A virtual simulation of Coulomb's Law that allows students to	3 slider, canvas simulasi real

			manipulate variables: charge magnitudes (q_1 , q_2) and the distance between charges (r).	
7	Educational Games Page 	Interactive game	A game based on the concept of static electricity, in which students drag electric charges to the correct zones, answer questions while playing, and build an understanding of the attraction and repulsion of charges	It features a scoring system, progressive levels, and lives to motivate learning.
8	Evaluation Page / Questions 	Scores Dashboard	10 multiple-choice questions on static electricity. Includes a progress bar, timer, and feedback	button, timer, and "Next" button
9	Student Attendance Page 	Google form	Digital attendance form for recording student attendance during class sessions.	Fields for name, class, and attendance number
10	Back Cover	Spotify	Motivational quotes to help you stay motivated to learn and not give up easily	Play and pause buttons



Develop

The development stage is the process of implementing the plan designed during the design stage (Johan et al., 2023). During the development stage, the product designed in the previous stage is tested for feasibility through a validation process conducted by experts before it is deemed ready for use in learning. In this study, the validation of the STATIC learning media was conducted by three junior high school (SMP/MTs) science and physics teachers acting as validators, using a 1–5 Likert scale instrument that covered six assessment aspects: content relevance, ease of access, practicality, ease of understanding, aesthetics, and efficiency. The scores obtained are shown in the following table:

Table 5. Validation Scores for the STATIC Learning Media

No.	Assessment Aspects	Score	Criteria
1.	Content Relevance	4,55	Highly Recommended
2.	Ease of Access	4,45	Highly Recommended
3.	Practicality	4,50	Highly Recommended
4.	Ease of Understanding	4,45	Highly Recommended
5.	Aesthetics	5,00	Highly Recommended
6.	Efficiency	4,65	Highly Recommended
Average		4,60	Highly Recommended

Table 6. Percentage of Validation Results for the STATIC Learning Media

No	Assessment Criteria	Percentage (%)	Criteria
1.	Content Relevance	91,0	Highly Recommended
2.	Ease of Access	89,0	Highly Recommended

3.	Practicality	90,0	Highly Recommended
4.	Ease of Understanding	89,0	Highly Recommended
5.	Aesthetics	100,0	Highly Recommended
6.	Efficiency	93,0	Highly Recommended
Average		92,0	Highly Recommended

The validation results, as shown in Tables 4 and 5, yielded an average score of 4.60, or 92.0%. When converted as described in the Methods section, this result falls within the 81%–100% range, which corresponds to the “Highly Acceptable” category. These validation results indicate that the STATIC learning medium which integrates Augmented Reality (AR) technology, PhET simulations, educational games, interactive quizzes, and artificial intelligence (AI) into a single platform, has met the suitability standards for use as a learning medium for static electricity concepts at the junior high school/MTs level, particularly in the context of schools in the Ponorogo region, which have long faced challenges in conducting hands-on static electricity experiments.

This means that the validators have determined that the material presented in STATIC aligns with the core competencies and learning needs for static electricity at the junior high school level. Furthermore, the ease of access aspect received a score of 4.45 (89.0%), confirming that STATIC is easily accessible via both laptops and smartphones without the need for complex additional devices, a distinct advantage, particularly for schools facing challenges due to limited physics lab facilities. The practicality aspect received a score of 4.50 (90.0%), reflecting the successful development and integration of various instructional features, including AR, PhET, educational games, quizzes, and AI, into a single platform called STATIC, making it easier for teachers and students to learn without switching between different applications. This practicality also contributed to the efficiency aspect, which received a score of 4.65 (93.0%), the highest score after aesthetics. This high efficiency score reinforces the finding in the introduction that more in-depth learning of static electricity is rarely conducted in practice due to limited access to equipment. The ease-of-understanding aspect received a score of 4.45 (89.0%). This score is consistent with the abstract nature of static electricity material. The integration of AR into STATIC consistently improves students’ conceptual understanding compared to conventional media due to its ability to present interactive three-dimensional objects. In addition to AR, the integration of

PhET simulations into STATIC also contributes to ease of understanding (Banda & Nzabahimana, 2021). The aesthetic aspect received the highest score among all evaluation aspects, namely 5.00 (100.0%). This perfect score indicates that STATIC's visual presentation, including its layout, color selection, icons, and interface elements, was deemed highly appealing by the validators.

When compared to several similar studies on the development of educational media, STATIC's feasibility score of 92.0% falls within a range consistent with previous studies. What distinguishes STATIC from previous research is the integration of artificial intelligence (AI) as an additional component alongside AR and PhET. Although the validation results at the "develop" stage indicated the "Highly Feasible" category across all aspects, there are several limitations that need to be noted. First, validation was conducted by only three teachers serving as expert/practitioner validators; thus, the results obtained primarily reflect feasibility from the educators' perspective and do not yet account for student outcomes. Second, this study used a 3D model that remained in the development phase without proceeding to the dissemination phase; thus, the effectiveness of STATIC in improving conceptual understanding and student learning outcomes has not yet been empirically tested through direct classroom implementation. Therefore, follow-up research, such as direct field trials, is highly recommended to measure the actual impact of STATIC on student learning outcomes.

Overall, the results of this development phase confirm that STATIC is valid and suitable in terms of content, accessibility, practicality, ease of understanding, aesthetics, and efficiency, as assessed through expert validation. This indicates that STATIC meets the quality standards expected of educational media designed to help address various issues particularly those related to static electricity which have long been hindered by a lack of in-depth practical experiments in schools, especially in the Ponorogo region. However, since the validation assesses the product's suitability rather than its actual impact on learning, the extent to which STATIC effectively addresses these issues in real world practice has not yet been empirically confirmed and requires further testing during the implementation phase. Nevertheless, the integration of AR, PhET simulations, educational games, quizzes, and AI into a single platform makes STATIC a suitable innovation for science education, which must continue to adapt to developments in digital technology in the era of education, especially in the 21st century.

CONCLUSION

This innovation successfully developed STATIC (Smart Augmented Technology and AI for Transformative Interactive Concept Learning in Electrostatics), a digital learning platform that integrates Augmented Reality (AR), PhET Interactive Simulations, Artificial Intelligence (AI), educational games, and interactive quizzes into a single integrated platform for teaching static electricity at the junior high school level. Expert validation by three science teachers yielded an average score of 4.60 (92.0%), placing STATIC in the “Highly Recommended” category across all six evaluation aspects, which include content relevance, ease of access, practicality, ease of understanding, aesthetics, and efficiency. These results demonstrate that STATIC is a valid and appropriate educational media application capable of addressing the challenges of teaching the abstract concept of static electricity in schools with limited laboratory facilities, particularly in the Ponorogo region. The integration of various digital platforms into a single, easily accessible application represents a new innovation compared to previous studies that implemented AR, PhET, and AI separately. However, this innovation has several limitations. Validation was conducted by teachers; student respondents were not involved, and the research was limited to the development stage without proceeding to dissemination or field testing. Consequently, the impact of using the STATIC application on student learning outcomes and conceptual understanding has not yet been empirically verified. Therefore, further research is strongly recommended to involve direct implementation in the classroom and to measure the effectiveness of STATIC in improving students’ achievement, motivation, and engagement in learning about static electricity.

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