Innovating Education Online Crafting Dynamic Learning Environments

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Abstract

Web-based learning environments have changed the traditional way of teaching to be more interactive and adaptive. However, there are challenges in making e-learning designs effective, aesthetically appealing and easy to use, and capable of improving learning outcomes and changing learning behaviors. This study investigates the influence of web-based learning environments on STEM education, focusing on the aesthetic appeal, user-friendliness and appropriateness of the visual design of mobile websites. The research objective is to evaluate the effectiveness of e-learning designs that include the incorporation of creativity, structured approaches, and evidence-based practices to improve learning outcomes and change learning behaviors. The research methodology involved literature analysis, content organization, and integration of interactive instructional design and multimedia elements. Merrill's Principles of First Instruction and the SAM Model were used as the basis of learning theory. Evaluation was conducted on modularity, scalability, codebase security, and user experience through navigation, intuitiveness, accessibility, and overall user happiness. The GUI design is accessible via PC/Laptop and Android and iOS-based mobile devices. The results show that comprehensive instructional design and the use of multimedia learning can improve learning outcomes. The integration of multimedia content such as videos, images, and interactive simulations within the web learning environment can increase engagement and facilitate effective learning. media experts and programming experts evaluated the visual and technical aspects of the website, providing recommendations to improve usability and performance. users also evaluate the website's ability to facilitate stem learning and report usability issues that could be improved. regular performance monitoring and testing, along with implementing best practices, can improve website quality and performance. fixing usability issues and improving website performance will provide a better learning experience for users.

Keywords: SAM Model; STEM Education; Online Courses; Web-Based Learning Environments

Introduction

The historical development of online education has been intricately intertwined with the evolution of information technology and educational technologies, as evidenced by the constantly changing landscape of instructional design and delivery methods. The foundational concepts of online education have undergone significant transformations, driven by the need to adapt to rapidly evolving environments. As highlighted by Pahl (2007) the design and maintenance of educational systems in online environments require a proactive approach to address the challenges posed by constant change and evolution. Moreover, Diane McDonald, Emma McCulloch (2010) emphasizes the profound impact of technology on educational practices, urging institutions to manage changes effectively to prevent disruptions in service quality and staff engagement. These insights underscore the critical importance of understanding the historical context of online education in

designing comprehensive and adaptive web-based learning environments. As educators and developers navigate the complexities of integrating technology into educational processes particularly in STEM education, a nuanced exploration of the historical trends in online education can provide valuable insights for enhancing the design and management of effective digital learning platforms. The objectives of integrated STEM education Goals are explicit declarations of the desired outcomes that the developer of a certain educational intervention aims to achieve. The significance of prioritizing objectives in the development of educational interventions cannot be overstated, since goals serve as the catalyst for an iterative process of educational transformation (National Academy of Engineering and National Research Council, 2014).

Web-based learning environments have transformed educational practices, necessitating a shift from traditional instructional methods to interactive and engaging approaches (P. Allen, Withey, Lawton and Aquino, 2016). Effective e-learning design involves combining creativity, structured approaches, and practices grounded in evidence to encourage changes in behavior and improve learning results. The purpose and scope of the research play a pivotal role in shaping the direction and outcomes of the investigation. Within this framework, techniques from behavior analysis, as discussed in (Pahl, 2007), play a crucial role in evaluating active learning strategies implemented through web tutorials. Furthermore, the exploration of linking Virtual Learning Environments (VLEs) with digital libraries, as highlighted in Currier (2001) underscores the importance of understanding end-user perspectives and institutional considerations in optimizing web-based educational platforms. By integrating insights from these sources, alongside the principles of success-based design and the evolution of instructional design paradigms outlined in the extracted knowledge, this comprehensive scientific study aims to delineate effective strategies for designing web-based learning environments that promote interactive, collaborative, and behavior-enhancing experiences for learners in diverse educational settings.

In designing web-based learning environments, a critical aspect to consider is the cognitive processes involved in online learning. Drawing from scholarly discussions, it is evident that the Community of Inquiry (COI) framework emphasizes teaching presence, social presence, and cognitive presence to foster deep online learning experiences (M. W. Allen, 2011). Design plays a pivotal role in shaping the effectiveness and success of STEM learning environments, particularly in the realm of web-based educational platforms (Mangaroska and Giannakos, 2018). Recognizing the intricate interplay between cognitive activity and design quality is imperative for optimizing learning outcomes (Mangaroska and Giannakos, 2018). As evidenced in the literature, the significance of design in enhancing students' writing skills through computer-mediated environments has become increasingly apparent (Zatserkovnyi, 2023). Moreover, in the context of enterprise big data mining systems, meticulous design considerations are essential for empowering decision-making processes and fostering business intelligence (Udeh, Orieno, Daraojimba, Ndubuisi and Oriekhoe, 2024).

In designing web-based learning environments, a pivotal aspect lies in comprehensively understanding user needs and preferences to ensure optimal learning outcomes (Ramadhan, Meisya, Jannah and Putro, 2023). Through a user-centered design approach, methods such as spatial walkthroughs, card sorting, and experience curve mapping, as outlined in (Babapour and Cobaleda-cordero, 2020), offer valuable insights into the interrelations between users and their surrounding environment. Incorporating these approaches can help educators and developers gather data on user experiences to enhance platform customization. Recognizing user needs is key in building effective web-based learning environments that drive successful educational results (Lin, Wen, Jou and

Wu, 2014). This holistic understanding of user needs is essential for creating effective and user-centric web-based learning environments that foster successful educational outcomes. A crucial aspect is the integration of User Experience (UX) Design Principles to enhance the overall effectiveness of the educational platform. User-Centered Design (UCD) methodologies, as explored in Niki Lambropoulos (2017) They propose three key factors ease of use, clear facilitation, and motivation to engage.

The involvement of stakeholders and users in the Requirements Engineering (RE) process, as highlighted in Schön, Thomaschewski and Escalona (2017) is essential for establishing a collaborative environment and ensuring constant feedback loops to tailor the platform to user needs. By incorporating elements from behaviorism, cognitivism, and constructivism, as suggested in (Michael, 2007), designers can create engaging and effective learning experiences that lead to measurable results. In designing web-based learning environments, the application of instructional design theories plays a pivotal role in ensuring the effectiveness and efficiency of educational strategies (Magdalena, Syaifulloh and Salsabila, 2024). By considering components such as learners' needs analysis, learning objectives, instructional materials, and assessment methods, a comprehensive ID model tailored for web-based learning environments can facilitate a structured and flexible approach to instruction. Through a mix sequence approach that combines theoretical frameworks with practical applications, educators can optimize the instructional process, promote learner-centered experiences, and ultimately improve performance outcomes. This deliberate incorporation of instructional design theories supports the creation of dynamic and interactive online learning experiences that align with the evolving demands of digital education (Akbar et al., 2023).

In an effort to develop effective web-based learning media for STEM education, previous research has shown that the development of STEM application-based learning media using the ADDIE model can produce products that are valid, feasible, and practical to use. Yadi, Santosa, Sari, Putri and Rusdi, (2023) found that the learning media they developed received very valid ratings from material, media, and language experts, as well as positive responses from lecturers and users in feasibility and practicality tests. Previous research conducted by Firdaus and Hamdu, (2020) showed that the development of STEM-based mobile learning applications can provide a better understanding of the implementation of STEM learning in elementary schools with video media. Through the Focus Group Discussion (FGD) method, the development of this application includes enrichment modules, lesson plans, media, student worksheets, test questions, and performance assessments. This study investigates the influence of web-based learning environments on STEM education, focusing on the aesthetic appeal, user-friendliness and appropriateness of the visual design of mobile websites. The research objective is to evaluate the effectiveness of e-learning designs that include the incorporation of creativity, structured approaches, and evidence-based practices to improve learning outcomes and change learning behaviors.

Methods

This study used a mixed-methods approach to evaluate the visual design aspects of the mobile website, focusing on attractiveness, usability, suitability for STEM learning, and perceived value. Data collection involved two expert evaluations (media and programming) and user feedback from 20 grade 7 students and 5 teachers at Darul Arifin School in Pakujaya and Pandeglang, Banten. The research methodology included a literature review to inform instructional design and multimedia integration practices, needs analysis to identify learners' needs, content structuring for curriculum organization, and interactive instructional design with multimedia integration. The research instrument

consisted of a questionnaire assessing visual design appeal, usability, suitability for learning, and perceived value, with Likert scale items (1–5) addressing aspects such as layout, color scheme, typography, images, and technical aspects such as coding standards, functionality, and performance. Data collection involved qualitative and quantitative analysis to evaluate the effectiveness and usability of the website, focusing on improvements to enhance educational outcomes and user satisfaction.

Result And Discussion

1. GUI (Graphical User Interface) Design

The GUI design created can be accessed both via PC/Laptop and mobile devices. When designing a graphical user interface (GUI), it's important to consider two main factors display characteristics and user or learner characteristics.

Display characteristics involve:

a. Addressing Task Goals: Displays should align with learning task objectives. For instance, diagrams should illustrate not only system components but also their interactions for tasks involving cause-and-effect relationships or system behaviors.
b. Providing Explanations and Guidance: Visual displays should be accompanied by explanations and guidance to enhance understanding. Simply adding visual displays to verbal material is insufficient guidance is necessary for effective learning.
c. Spatial and Timely Coordination with Text: Presenting visual and verbal information together facilitates learning by allowing learners to form connections between them. Simultaneous use of images and auditory narration can help build connections without overloading working memory.

Learner characteristics include:

a. Content Knowledge: Prior knowledge impacts learners' comprehension and use of explanatory diagrams. High-knowledge individuals may extract relevant information better, but the effectiveness of diagrams may vary based on learners' prior knowledge.
b. Visuospatial Ability: The ability to manipulate mental images affects how students process graphics. Students with low spatial ability may have difficulty with diagrams, as constructing visual representations in working memory may overload cognitive resources.

The design of the graphical user interface is as follows:

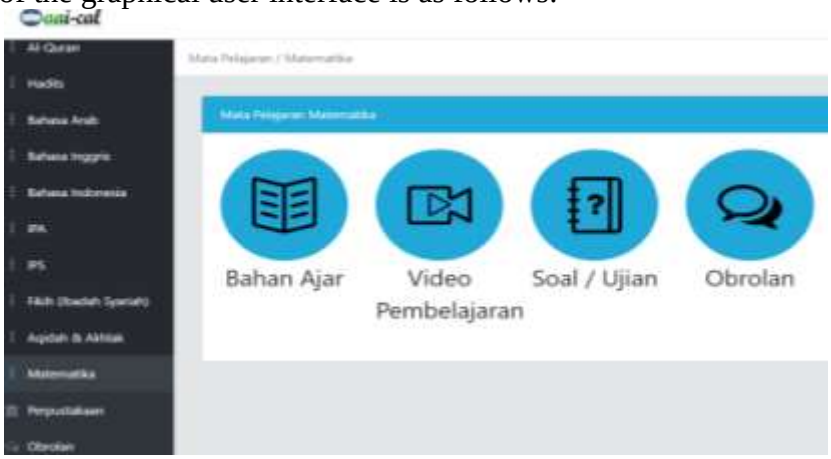

Figure 1. Graphical User Interface Design

The user has the ability to download teaching materials and videos, which can subsequently be accessed for reading and offline video playback. The internet connection is solely necessary for downloading, but the instructional materials and videos can be accessed offline. The purpose is to address the limitations imposed by the expenses associated with internet connectivity.

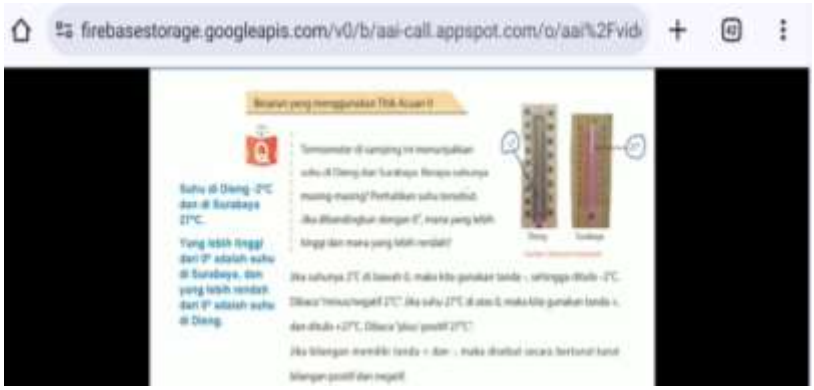

Figure 2. STEM Learning Presented Through A Visual Display

The operating system utilized for accessing can support both the Android and the iPhone Operating System (iOS).

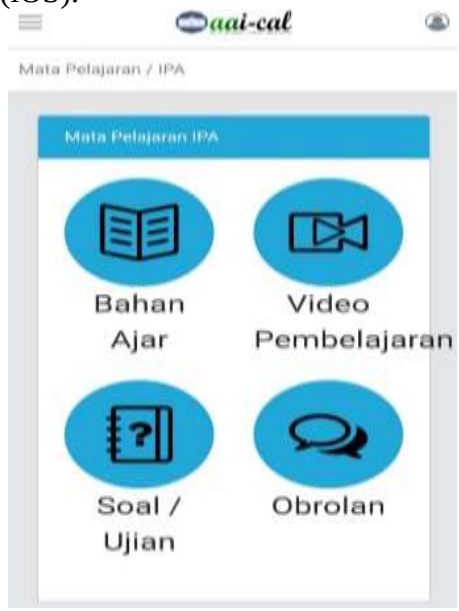

Figure 3. Home Menu (Web-Based Learning Environments), Display On Mobile Devices

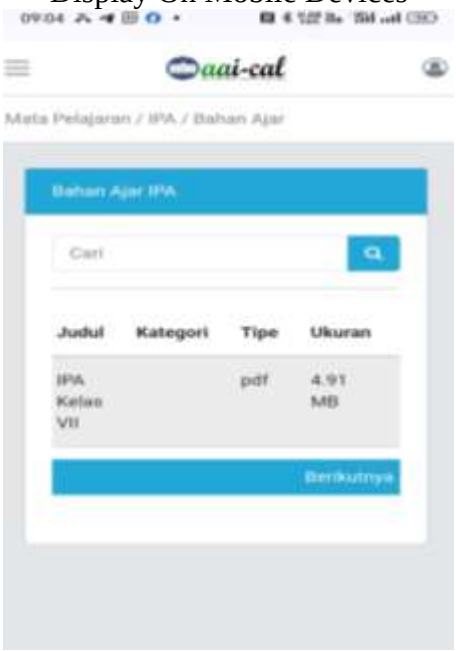

Figure 4. STEM Science Teaching Materials Menu (Accessed through Mobile Devices)

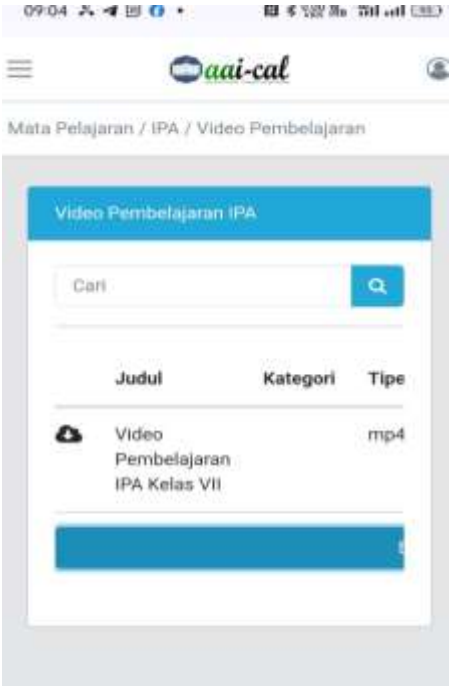

Figure 5. STEM Science Learning Video Menu (Accessed through Mobile Devices)

2. Data Extraction Obtained From Experts And Users.

Media experts focus on visual design and branding, programming experts assess technical functionality, and users provide feedback on usability and user experience. Collaboration between these stakeholders helps ensure the development of a well-designed and user-friendly website. Experts are capable of navigating challenges posed by both emerging technologies and legacy software. They utilize process layers, methods, and tools to efficiently develop high-quality software (Roger S.Pressman, 2015).

Media experts, programming experts, and users each have specific tasks when assessing website design:

a. Media Experts:

1) Evaluate the visual aspects of the website design, such as layout, color scheme, typography, and imagery.
2) Assess the overall aesthetic appeal and branding consistency of the website.
3) Provide feedback on the usability of multimedia elements, such as images, videos, and audio clips.
4) Consider the alignment of the design with current trends and industry standards in web design.

b. Programming Experts:

1) Review the technical aspects of the website design, including coding standards, functionality, and performance.
2) Assess the responsiveness and compatibility of the website across different devices and browsers.
3) Evaluate the efficiency and maintainability of the codebase, including factors such as modularity, scalability, and security.
4) Provide recommendations for optimizing code and improving website performance.

c. Users:

1) Evaluate the user experience (UX) of the website, focusing on ease of navigation, intuitiveness, and accessibility.
2) Provide feedback on the clarity and effectiveness of content presentation, including text readability and organization.

3) Test interactive elements, such as forms, buttons, and menus, for functionality and user-friendliness.
4) Report any usability issues or obstacles encountered during their interaction with the website.

A questionnaire with Likert scales was used as the test instrument for data collection. The data to be obtained from the questionnaire is then measured with the following score interpretation:

Table 1. Score Interpretation

Score	%	Interpretation
1	0 - 20	Bad
2	21- 40	Poor
3	41- 60	Moderate
4	61- 80	Good
5	81-100	Excellent

$$Score\ Interpretation\ Percentage = \left(\frac{\sum actual\ scores}{\sum maksimum\ possible\ scores}\right) \times 100\%$$

Table 2. Displays An Assessment Of The Website's Attractiveness, Usability, Suitability For Learning Goals, And Perceived Value As Evaluated By Media Experts, Programming Experts, and Users

Aspect	Media Experts	Programming Experts	Users
Attractiveness	Evaluate visual elements such as layout, color scheme, and imagery to assess the website's overall aesthetic appeal.	Focus on technical aspects that contribute to visual appeal, such as responsive design and compatibility across devices.	Consider visual appeal and design coherence in terms of ease of navigation and engagement with multimedia content.
Usability	Assess the usability of multimedia elements like images, videos, and audio clips in terms of accessibility and functionality.	Review technical functionalities and efficiency of interactive elements, ensuring smooth navigation and responsiveness.	Evaluate ease of navigation, clarity of content presentation, and effectiveness of interactive features for learning purposes.
Suitability for Learning	Provide feedback on the effectiveness of multi-media elements for STEM learning purposes and alignment with educational goals.	Evaluate the integration of instructional content and interactive features to support STEM learning objectives effectively.	Assess the website's ability to facilitate STEM learning activities, provide relevant resources, and engage learners effectively.

Perceived Value	Consider the overall value proposition of the website in terms of the quality and relevance of content and learning resources.	Review the efficiency and effectiveness of the website's functionalities in achieving STEM learning outcomes.	Evaluate the perceived usefulness and impact of the website on STEM learning progress and motivation.

The following tables display the questionnaire responses, scores, and interpretations for media development products in both PC/Laptop and mobile versions. The participants include media experts, programming experts, and users:

Table 3. Responses, Scores, And Interpretations Conducted By Media Experts

Experts/ Users	Tasks	Using PC/Laptop		Using Mobile Devices	
		Average Score	Interpretation	Average Score	Interpretation
Media Experts	Evaluate the visual aspects of the website design, such as layout, color scheme, typography, and imagery	85%	Excellent	85%	Excellent
	Assess the overall aesthetic appeal and branding consistency of the website.	85%	Excellent	82,5%	Excellent
	Consider the alignment of the design with current trends and industry standards in web design.	80%	Good	82,5%	Excellent

Provide recommendations for on the usability of multimedia elements (images, audio/videos):

E1: The images used on the website are visually appealing and relevant to the content. Additionally, the videos embedded (using you tube) in the tutorials are informative.

E2: As for the audio clips, they enhance the learning experience, but the volume levels vary, resulting in inconsistent audio quality. Overall, optimizing the loading speed of images, improving video playback controls, and ensuring consistent audio quality would significantly enhance the usability of multimedia elements on the website.

Table 4. Responses, Scores, And Interpretations Conducted By Programming Experts

Experts/ Users	Tasks	Using PC/Laptop		Using Mobile Devices	
		Average Score	Interpretation	Average Score	Interpretation

Programming Experts	Review technical aspects (coding s, functionality, performance) that contribute to visual appeal, such as responsive design and compatibility across devices.	80%	Good	85%	Excellent
	Assess technical functionalities and efficiency of interactive elements, ensuring smooth navigation and responsiveness and the integration of instructional content and interactive features to support STEM learning objectives effectively.	85%	Excellent	80%	Good
	Evaluate efficiency and maintainability of codebase (modularity, scalability, security) and effectiveness of the website's functionalities in achieving STEM learning outcomes.	80%	Good	82,5%	Excellent

Provide recommendations for optimizing code and improving website performance:

E1: To improve website performance, it is recommended to optimize the codebase by minimizing unnecessary scripts and reducing file sizes. This can be achieved by implementing techniques such as code minification and compression.

E2: It is important to prioritize critical rendering paths and utilize asynchronous loading for non-essential resources to enhance overall responsiveness.

Table 5. Responses, Scores, And Interpretations Conducted By Users

Experts/ Users	Tasks	Using PC/Laptop		Using Mobile Devices	
		Average Score	Interpretation	Average Score	Interpretation
Users	Evaluate user experience (UX) in			82,5%	Excellent

	terms of navigation, intuitiveness, accessibility and clarity of content presentation (text readability) and effectiveness of interactive features for learning purposes.	85%	Excellent		
	Assess the website's ability to facilitate STEM learning activities, provide relevant resources, and engage learners effectively.	85%	Excellent	80%	Good
	Evaluate the perceived usefulness and impact of the website on STEM learning progress and motivation.	82,5%	Excellent	80%	Good
	Test interactive elements for functionality and user-friendliness	90%	Excellent	85%	Excellent

Report usability issues (provide by teachers) encountered during interaction with the website.

U1: Menu navigation was clear

U2: The text on certain pages was too small and difficult to read, especially on mobile devices, impacting the overall accessibility of the website.

U3: Addressing these usability issues would greatly improve the usability and user-friendliness of the website.

U4: Leveraging browser caching and content delivery networks (CDNs) can help reduce server load and improve page load times.

U5: Regular performance monitoring and testing, along with implementing best practices such as lazy loading for images and optimizing database queries, will further optimize code and improve website performance.

The design of a GUI (Graphic User Interface) is crucial for effective learning, as it should align with learning objectives, provide explanations, and coordinate with text. Learner characteristics include prior knowledge and visual ability. The GUI design includes downloading teaching materials and videos, which can be accessed offline. The website's design is tested by media experts, programming experts, and users. Media experts evaluate the visual design, branding, usability of multimedia elements, and alignment with industry standards. Programming experts assess technical functionality, responsiveness, and codebase efficiency. Users evaluate the user experience, navigation, and clarity of content presentation. A questionnaire with Likert scales was used for data collection. Research shows that factors such as visual appeal, usability, compatibility with learning objectives, and perceived value greatly influence the effectiveness of a web-based learning medium.

Visual appeal includes aesthetic and graphic design aspects that visually attract users' attention. This is important because an attractive appearance can increase user interest and engagement with learning content. Usability refers to how easily users can interact with the website and find the information they are looking for without a hitch. Usability evaluation involves identifying problems such as complicated navigation, inappropriate text size, or unintuitive page layout. Solutions to these problems often involve regular performance monitoring and testing to ensure the website remains responsive and simple to use. Suitability to learning objectives refers to the extent to which the website supports and facilitates the achievement of learning goals, particularly in the context of STEM education. Media experts and developers typically conduct this evaluation, assessing whether the website's content, structure, and technical features align with the targeted learning needs. The user's perceived value is their perception of the benefits and value of using the website to support their learning. It encompasses not only functional and informative aspects, but also the overall user experience, including psychological factors such as satisfaction and confidence in using the site.

In the process of developing web learning media, the collection of questionnaire responses, scores, and interpretations from various parties, such as media experts, programming experts, and users, is extremely important. They provide different perspectives that, together, help ensure that the developed product not only functions well technically but also meets the needs and expectations of the end users. The results of this study are consistent with Yadi, Santosa, Sari, Putri & Rusdi, (2023) research which found that the learning media they developed received very valid assessments from material, media, and language experts, as well as positive responses from lecturers and users in feasibility and practicality tests. This research also supports the findings of Firdaus & Hamdu (2020), where the development of STEM-based mobile learning applications can provide a better understanding of the implementation of STEM learning with video media.

Conclusion

This study aims to evaluate the visual design, usability, suitability for STEM learning objectives, and perceived value of a mobile website. The results show that comprehensive instructional design and the use of multimedia learning can improve learning outcomes. The integration of multimedia content such as videos, images, and interactive simulations within the web learning environment can increase engagement and facilitate effective learning. Media experts and programming experts evaluated the visual and technical aspects of the website, providing recommendations to improve usability and performance. Users also evaluate the website's ability to facilitate STEM learning and report usability issues that could be improved. Regular performance monitoring and testing, along with implementing best practices, can improve website quality and performance. Fixing usability issues and improving website performance will provide a better learning experience for users.

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