JURNAL INOVASI

Teknologi Pendidikan

Volume 13, No 2, June 2026

9 772460 717002

9 772407 096009

JURNAL INOVASI Teknologi Pendidikan

Volume 13, No. 2, June 2026

Volume 13, No 2, June 2026

ISSN 2407-0963 (print)
ISSN 2460-7177 (onlne)

JURNAL INOVASI

TEKNOLOGI PENDIDIKAN

IPTPI APS-TPI

Ikatan Profesi Teknologi Pendidikan Indonesia & Asosiasi Program Studi Teknologi Pendidikan Indonesia
Bekerja sama dengan
Fakultas Ilmu Pendidikan dan Psikologi Univesitas Negeri Yogyakarta

JURNAL INOVASI
Teknologi Pendidikan

Publisher:
Ikatan Profesi Teknologi Pendidikan Indonesia (IPTPI) & Asosiasi Program Studi Teknologi Pendidikan Indonesia (APS-TPI)
in Cooperation with
Faculty of Education, Yogyakarta State University

Jurnal Inovasi Teknologi Pendidikan published in March, June, September and December

Correspondence: Faculty of Education of Yogyakarta State University
Kampus Karangmalang, Yogyakarta, 55281
Telp. (0274) 550835, Fax. (0274) 520326

Email: teknodik@uny.ac.id
Website: http://journal.uny.ac.id/index.php/jitp

Volume 13, No 2, June 2026

ISSN 2407-0963 (print)
ISSN 2460-7177 (onlne)

JURNAL INOVASI

TEKNOLOGI PENDIDIKAN

IPTPI APS-TPI

Ikatan Profesi Teknologi Pendidikan Indonesia & Asosiasi Program Studi Teknologi Pendidikan Indonesia
Bekerja sama dengan
Fakultas Ilmu Pendidikan Univesitas Negeri Yogyakarta

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (132-142)
Online: http://journal.uny.ac.id/index.php/jitp

Development of student worksheets with digital literacy content to increase students' learning interest

Hetty Purnamasari, Ninik Mardiana*, Nuril Huda, Iwan Sugianto, Siti Nabila
Universitas Dr. Soetomo Surabaya, Indonesia.
* Corresponding Author. E-mail: ninik.mardiana@unitomo.ac.id

ARTICLE INFO

Article History
Received:
25 February 2026;
Revised:
8 June 2026;
Accepted:
9 June 2026;
Available online:
30 June 2026.

Keywords
ADDIE; Development;
Digital literacy;
Interest; Worksheet

ABSTRACT

Worksheets are necessary as part of learning tools. This study aims to develop a digital literacy-based Student Worksheet for Indonesian language learning at the junior high school level and to test its validity, practicality, and effectiveness. The study uses a Research and Development (R&D) model with the ADDIE approach (analysis, design, development, implementation, and evaluation). The research subjects consisted of material experts, media experts, linguists, Indonesian language teachers, and 15 seventh-grade students. The object of this study was a digital-based worksheet product using a flipbook application. Data were collected through interviews for worksheet validation, student perception questionnaires, and observations of student activities and enthusiasm. The results showed that the developed worksheet was in the valid category based on the assessment of three validators, covering aspects of material suitability (point 4.4 valid category), media display, and language quality. The worksheet's attractiveness test through a student response questionnaire showed that the worksheet was easy to use, interesting, and relevant to the needs of digital-based students. Observations of student engagement also showed increased enthusiasm and sincerity in completing assignments. This worksheet also fills the gap in learning listening skills, so it can be used for classroom learning.

How to cite:
Purnamasari, H. et al., (2026). Development of student worksheets with digital literacy content to increase student' learning interest. *Jurnal Inovasi Teknologi Pendidikan, 13*(2), 132-142. https://doi.org/10.21831/jitp.v13i2.96063

INTRODUCTION

Indonesian language learning plays a strategic role in developing students' literacy skills, including those in junior high school (Nurgiyantoro et al, 2020). Language skills such as reading, listening, writing, and speaking form an important foundation for cross-subject learning (Sadiku, 2015). However, the reality on the ground shows that junior high school students' language skills are still below standard (Liu, 2023). Many students struggle to comprehend reading material, express ideas in writing, or express opinions verbally in a structured manner. This situation not only impacts Indonesian language learning outcomes but also impacts other subjects that require text comprehension (Nuryanti et al., 2023).

One of the causes of low student literacy skills) is the lack of innovation and variety in the learning media used in the classroom (Lee, 2016). Student worksheets, which should be a tool in building student understanding and skills, are generally still compiled in a conventional format (Darmawan et al, 2024), namely containing materials and assignments that are packaged by students

to complete through writing, and are less interactive. Worksheets such as this are not fully able to meet the learning needs of students in the digital era, which is full of visual, audio, and interactive information (Kesumawardani et al., 2024).

In the midst of the increasingly rapid development of digital technology, the world of education is required to adapt to be able to create a generation that has academically intelligent thinking, but is also digitally "literate" (Akayoglu et al., 2020; Caton et al., 2025; Muchsini & Siswandari, 2020; Purwaningrum & Leksono, 2022; Harianto & Karjadi, 2024; Stefany, 2024). This challenge is particularly relevant in Indonesian language learning at the junior high school (SMP) level, where students need to be trained to understand and use the language effectively in various contexts, including digital contexts. One of the important challenges currently facing us is how to effectively utilize digital technology to improve students' language skills, including reading, listening, writing, and speaking. Speech skills (Lestari & Jusra, 2022).

On the other hand, junior high school students today live in a dynamic digital environment (Porat et al., 2018; Sutarni et al., 2021). They are familiar with technologies such as gadgets, social media, and various digital applications (Lai & White, 2012). Unfortunately, their familiarity with technology is not always accompanied by adequate digital literacy skills. Most use it only for entertainment, without being directed towards meaningful learning activities (Yun & Kim, 2025). The Indonesian language learning process in schools often still takes place conventionally (Kasim et al., 2026). Teachers tend to use printed textbooks and learning methods that do not or do not optimally engage students more actively in the learning process. This has an impact on limiting students' exploration space in developing language skills, including reading, writing, speaking, and listening.

However, outside the classroom, students are accustomed to using digital devices (such as cell phones) in their daily lives, although they do not necessarily utilize them optimally to support the learning process (Sutrisno, 2022). In fact, through these devices, students can obtain and access information and learn from a wider range of learning resources, improve critical thinking skills, and develop creativity in language. One of the hopes of teachers is to foster an interest in reading, listening, writing, and speaking through digital devices. This digital reading integration not only increases the accessibility of reading materials and media in schools, but can also make the learning process more varied, interactive, and interesting, thereby encouraging students to be more enthusiastic in developing their reading, listening, writing, and speaking skills.

Student Worksheets as part of learning media can be developed to bridge this need. This situation indicates an opportunity to integrate digital literacy skills into Indonesian language learning. One approach is to develop Student Worksheets that not only contain learning tasks but are also designed based on digital literacy and encourage students to access, understand, and produce information wisely. With this approach, learning will not only be more engaging and contextual, but also able to develop language skills that are appropriate to the demands of the digital era (Yulianti et al., 2024).

Based on the literature review and the problems that have been identified, this research is based on the idea that: (1) The literacy skills of junior high school students are still low, especially in the four Indonesian language skills; (2) Conventional Worksheet has not been able to answer the challenges of 21st century learning, due to the lack of interactive, visual elements, and connectedness to the digital context; (3) Integrating digital literacy into Worksheet can be a strategy to improve students' language skills, because students are invited to actively access, understand, and reflect on information through digital media; (4) The development of digital literacy-based Worksheet is expected to produce valid, practical, and effective learning media in improving the language skills of junior high school students.

Therefore, research on the development of digital literacy-based student worksheets is crucial (Razak et al, 2022). The goal is to design learning tools relevant to the characteristics of today's students (Choo & Taha, 2023), namely improving digital literacy while enhancing their overall Indonesian language skills. Meanwhile, Dr. Soetomo Junior High School students still use Worksheets from a publisher they collaborate with.

The objectives of this research are: (1) Developing a digital literacy-based Worksheet that suits the needs and literacy abilities of junior high school students in learning Indonesian; (2) Knowing the quality of a digital literacy-based Worksheet based on validity and attractiveness tests; (3) Analyzing the influence of using a digital literacy-based Worksheet on improving junior high school students' language skills.

The novelty of this research is the emphasis on improving students' digital literacy and improving junior high school students' language skills, which include reading, writing, listening, and speaking skills. This research is expected to contribute to the development of Indonesian language learning theory based on digital literacy, as well as enrich the literature on interactive learning media in the digital era. In practical benefits: (a) For Teachers: Providing alternative learning media that are innovative and relevant to current student needs; (b) For Students: Help students develop language skills through more engaging and contextual learning, as well as train their digital literacy skills; (c) For Schools: To be a reference in designing learning strategies integrated with information and communication technology; (d) For Further Researchers: Provide references and inspiration in developing digital based learning media in other subjects.

METHOD

This research is a research and development (Research and Development) that aims to produce a product in the form of a digital literacy-based Student Worksheet in Indonesian language learning for junior high school students, as well as to test the validity and attractiveness of the product (Prastowo, 2014; Sugiyono, 2019). The development model used is the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) (Yunita et al., 2024; Fitriyah et al., 2021; Saputra & Putra, 2021; Muslim et al., 2024), which is one of the systematic instructional development models commonly used in educational research.

The research subjects were seventh-grade students of Dr. Soetomo Surabaya Junior High School, Indonesian language teachers, and expert validators (media and language). The research objects were digital literacy-based worksheets developed and the language skills of seventh-grade junior high school students, aged 11-12. To find out students' perceptions about the attractiveness of the worksheets, they were distributed to 15 randomly selected junior high school students. This research object was chosen because seventh-grade students are expected to have mastered digital skills in QR scanning, data storage on drives, and file sharing activities from drives.

The instruments used in this study included: (a) worksheet validation sheets by experts. The experts, in this case, were Indonesian language teachers experienced in teaching Indonesian language courses, language experts, and learning media experts; (b) Student engagement observation sheets to observe student enthusiasm and commitment in completing the worksheet assignments; (c) Questionnaires on student and teacher responses to the worksheet. This was to determine perceptions of the appeal, benefits, and skill improvements gained after completing the worksheet. The validation sheet is given to teachers, language experts (Indonesian language lecturer who teaches Indonesian grammar), and learning media experts (lecturers in the learning technology study program who teach learning media) to assess the worksheet products. In the validation sheet, there is a column for filling in the assessment that must be filled in according to the question items.

The development of the Student Worksheet follows the five stages of the ADDIE model as follows Figure 1.

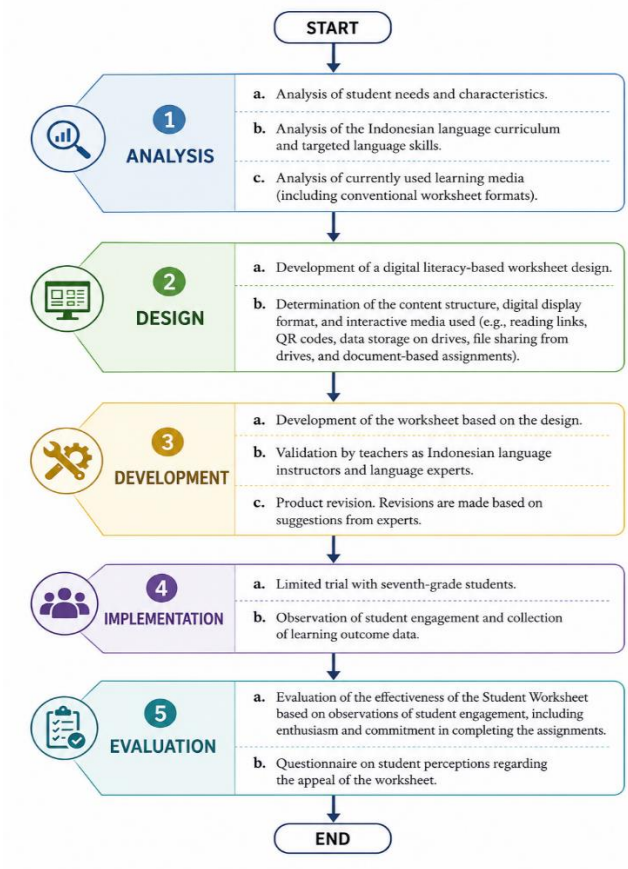

Figure 1. ADDIE Model

Data were collected through several techniques: (a) Observations of worksheet use in the classroom, (done when students work on the worksheet twice); (b) Interviews with experts (to explore expert opinions); (c) Questionnaires to determine appeal and responses to the product (given to students); (d) Expert validation to assess product quality in terms of content, media, and language. The data analysis techniques can be described as follows: (a) worksheet validity data is analyzed using interview techniques, then categorized into certain categories (very valid, valid, quite valid, invalid), (b) Interesting data is analyzed from student perception questionnaires, then the percentage of positive responses is calculated (with categories <49% respondents = not worthy, <50%<69% less worthy, <70%<85% = worthy, <86%<100% = very worthy), (c) Descriptive qualitative data from observations when students are working on assignments or interviews are analyzed descriptively to support quantitative findings.

RESULTS AND DISCUSSION

Results

Once the developed worksheet is complete, it needs to receive input from Indonesian language experts, learning media experts, and language experts. After that, it is tested on randomly selected students. This worksheet is available in both printed and digital (app-based) formats. The digital form can be accessed via students' mobile phones at https://online.fliphtml5.com/nabilahpbs/onui/. The worksheet covers four language skills: reading, writing, listening, and speaking. For reading, the worksheet directs students to scan a barcode containing the full text. For listening, the worksheet includes a barcode that directs students to an MP3 recording of the conversation. For speaking, students are instructed to record their speaking skills, upload them to their drive, and share the link with the worksheet answers. An example of the appearance of the digital-based worksheet, which looks the same as the printed one, is shown in the cellphone screenshot in the collage Figure 2 below.

Figure 2. Collage Showing the Contents of the Developed Worksheet

The data obtained in this study came from three main sources, namely the results of expert validation of digital literacy-based worksheet products, questionnaire data on students' perceptions of worksheet use, as well as effectiveness data obtained through language skills tests before and after worksheet use. From the results of interviews with 3 experts, consisting of a junior high school Indonesian language teacher and two other experts, the results were obtained as in the following Tables 1, 2, and 3.

Table 1. Indonesian Language Material Expert (by Junior High School Indonesian Language Teacher)

No.	Aspects Interviewed	Core Interview Results	Score	Category
1	Suitability of material with curriculum and learning outcomes	The material is in accordance with basic competencies/learning outcomes for class VII, with complete coverage	5	Very Valid
2	Accuracy of text selection	Relevant and representative text for learning purposes	4	Valid
3	Clarity of material	In summary: informative, but some things still need clarification.	4	Valid
4	Suitability of activities with learning objectives	Appropriate and constructivist-based activities	5	Very Valid
5	Quality of evaluation questions	The questions are clear, require understanding, and are varied.	4	Valid
Result of Material Worksheet			**4.4**	**Valid**

Table 2. Learning Media Expert (by Lecturer of the Master of Educational Technology Study Program)

No.	Aspects Interviewed	Core Interview Results	Score	Category
1	Appearance and neatness of design	Neat but still simple, not yet visually exploratory	4	Valid
2	Worksheet format consistency	Consistent structure (title, material, activities, reflection)	4	Valid
3	Integration of digital elements	There are QR codes, digital recordings, and digital posters, but they are not evenly distributed across all materials.	3	Quite Valid
4	Clarity of student work steps	Clear and systematic instructions	5	Very Valid
5	Suitability of worksheet with the characteristics of junior high school students	Appropriate, but the visual appearance needs strengthening	4	Valid
Quality Results of Worksheets as Learning Media			**4**	**Valid**

Table 3. Linguist (by Lecturer of Indonesian Language and Literature)

No.	Aspects Interviewed	Core Interview Results	Score	Category
1	Language standardization	Standard language, very few typos	5	Very Valid
2	Readability and clarity of sentences	Instructions are easy to understand; some sentences could be condensed	4	Valid
3	Uniformity of use of terms	Consistent terms, according to the learning domain	3	Quite Valid
4	Language suitability to the cognitive level of junior high school students	Already appropriate	4	Valid
Linguistic Quality Results			**4**	**Valid**

The digital literacy-based student worksheet validation process involved three validators: an Indonesian language subject matter expert (teacher), an instructional media expert (lecturer), and a language expert (lecturer). The three validators provided input, assessments, and recommendations for improvements to the quality of the student worksheet based on their respective areas of expertise. Validation data analysis showed that the developed student worksheet met the standards for content, presentation, language, and digital literacy integration required for Indonesian language learning at the junior high school level.

The core results of interviews with three experts indicate that this digital literacy-based worksheet is of good quality and is suitable for implementation in learning. The content aspect is considered accurate and relevant; the media aspect is considered to have met the principles of instructional design, although it needs visual reinforcement (due to the lack of illustrations, making it somewhat monotonous); and the language aspect is considered appropriate and communicative. The average overall assessment is in the category of "quite valid," "valid," or "very valid," indicating that the worksheet is ready for use in the limited trial stage after considering minor revisions from the experts.

Thus, the validation data analysis shows that the developed worksheet has met the criteria for the suitability of educational products, both in terms of material, media, and language. This product is not only in accordance with the demands of the curriculum, but also relevant to the needs of students in the digital era. Validation from the three experts provides a strong foundation for the implementation of the worksheet in Indonesian language learning, as well as opening up space for further development to improve the quality of digital literacy-based learning media.

Students' responses to the worksheets that have been tested on them, with a questionnaire containing questions with limited answers between agree and disagree, can be seen in the following Table 4.

Table 4. Results of Student Responses to Digital Literacy-Based Worksheet (number of students = 15 people)

No.	Rated Aspect	Number of Students Who Agree	Percentage	Category
1	Worksheet is easy to understand, and the instructions are clear	13	86.6%	Very worthy
2	The appearance of the worksheet is neat and quite attractive	11	73.3%	Worthy
3	Using QR codes/links/videos helps learning	14	93.3%	Very worthy
4	The material is appropriate to your abilities and is not confusing.	12	80%	Worthy
5	Learning activities feel fun and not monotonous	13	86.6%	Very worthy
6	Worksheet increases motivation to learn Indonesian	12	80%	Worthy
7	Worksheet is easy to use via a gadget/cellphone	14	93.3%	Very worthy

The feasibility test for the worksheet was conducted by distributing questionnaires to 15 students who acted as direct users during the limited trial phase. The questionnaire aimed to determine students' perceptions regarding ease of use, attractiveness of the display, clarity of instructions, and the usefulness of the worksheet in helping them understand digital literacy-based Indonesian language learning. Overall, student responses indicated that the digital literacy-based worksheet provided a more interactive learning experience and was able to encourage student engagement more optimally than a conventional worksheet. These results support the finding that digital-based learning media can improve students' motivation and language competence in the technological era.

Observations show that the use of digital literacy-based worksheets significantly increased student engagement. Students responded positively. Student enthusiasm was evident from the beginning of the activity, especially when they were asked to access materials via QR codes, open digital reading links, listen to dialogues stored in MP3 format that can be accessed by scanning the QR code, or produce digital work, namely recording student speaking practice. These technology-based activities provided a more engaging learning experience than using conventional worksheets. Conventional worksheets hindered the development of listening and speaking skills. Most students appeared curious and enthusiastic when directed to use digital devices. They actively scanned QR codes, discussed with peers, and attempted to solve the instructions provided. Enthusiasm was also evident in the way students explored the digital learning materials. Students appeared more focused and motivated when accessing materials through digital readings and recorded dialogues using digital devices. The interactive digital elements in the worksheets provided additional stimulus that made the learning atmosphere more dynamic and participatory.

Based on expert validation, student responses, and learning outcomes, it can be concluded that digital literacy-based student worksheets are of good quality as a medium for Indonesian language learning. These worksheets are feasible, practical, and effective because: 1) Content aspect: the material is aligned with the curriculum and is oriented towards strengthening the four language skills. 2) Media aspect: systematic flow and integration of digital technology support 21st-century learning. 3) Language aspect: instructions are clear, communicative, and appropriate to the students' developmental age. 4) Implementation aspect: the worksheet was received positively by students and significantly improved language skills.

Discussion

Research findings related to product validity confirm that the developed digital worksheet aligns with the concept of learning tool development (Falloon, 2020), which emphasizes content relevance, suitability to student characteristics, and linguistic quality. The three validators provided fairly consistent assessments, stating that the worksheet is suitable for use and meets the principles

of appropriateness of content, media, and language. This finding aligns with Prastowo (2014) theory, which states that good learning tools must meet systematic and communicative aspects and be aligned with learning objectives. Thus, the validity obtained strengthens the worksheet's position as a product that theoretically aligns with the framework for developing learning media.

In terms of appeal, student responses indicated that the digital literacy-based worksheets were positively received and easy to operate. The use of digitally-charged operations is also in line with Spante et al., (2018), which outlines the concept of digital literacy. Their high level of appeal led to students' enthusiasm and active participation in the worksheets. This also indicated that students did not encounter significant obstacles in accessing or completing digital-based assignments. This fact also demonstrates a match between the characteristics of Generation Z students, who are required to be familiar with devices, and the worksheet format that integrates QR codes, file uploads, and digital creation. These findings support research by Sutrisno (2022), which emphasizes that digital devices can increase learning engagement when pedagogically guided. In other words, technology is not only a tool but also a medium that conditions learning to be more interactive, collaborative, and contextual. From a pedagogical perspective, the results of this study demonstrate that a student-centered learning approach is more likely to be achieved when students engage in digital activities. The developed student worksheets provide space for creativity, opportunities for exploration, and independence in managing information. Therefore, these results support not only constructivist learning theory but also Indonesian language learning practices that integrate digital literacy as a holistic process for developing language competency.

This discussion also needs to consider the limitations of the study. The use of digital worksheets is highly dependent on the availability of devices and adequate internet access (Claro et al., 2018). Furthermore, teachers need to be digitally literate to optimally guide students. These factors indicate that the success of digital media implementation hinges not only on product quality but also on the readiness of its supporting ecosystem (Bond et al., 2021). This aspect provides a space for reflection for schools and further research to strengthen infrastructure support and technological competency for teachers. The emerging findings not only support previous research but also provide a new contribution in the form of integrated language skills with digital literacy. Therefore, this worksheet has the potential to be further developed as a cross-subject learning model that aligns with the dynamics of technology and the needs of today's students.

This research successfully developed a digital literacy-based student worksheet that meets the needs of Indonesian language learning in junior high schools. The resulting worksheet contains clear components, such as learning objectives, material summaries, digital reading materials, technology-based activities (QR codes, use of digital book applications, uploading digital files), and assignments that encourage students to actively construct knowledge. This worksheet meets the characteristics of digital-age students because it integrates activities relevant to the use of technology in students' daily lives.

The validation results from three validators, namely material experts, media experts, and language experts, indicate that the Student Worksheet is valid and suitable for use in learning. The material aspect is assessed as being in accordance with the curriculum and the scope of language skills. The media aspect shows that the worksheet display is systematic, easy to use, and quite effective in facilitating digital learning. The language aspect shows that the worksheet uses standard language, is communicative, and is appropriate for students' cognitive development levels. The worksheet is easy to understand, engaging, and supports digital-based learning. The quality of the worksheet meets the criteria for good learning media in three aspects: content, media, and language.

Digital literacy-based student worksheets have proven effective in improving students' language skills, including reading, listening, writing, and speaking. While conventional worksheets struggle to improve listening skills, digital-based worksheets eliminate this barrier in Indonesian language learning. These worksheets bridge students' language and digital literacy needs, making learning more interactive, contextual, and responsive to the challenges of education in the digital era. However, digital skills need to be developed from an early age, in line with the opinion of (van Laar et al., 2020). These worksheets not only enrich teachers' teaching tools but also contribute to the development of digital literacy-based learning theory and practice in schools.

CONCLUSION

The research findings on the development of digital literacy-based student worksheets for Indonesian language learning at the junior high school level have several important implications for education, both at the pedagogical and institutional levels, and for academic development. The worksheet products, which have been proven valid, practical, and effective, demonstrate that integrating digital literacy into learning tools can be a comprehensive strategy for improving language skills while simultaneously facilitating the learning needs of digital-generation students. These worksheets can be used by seventh-grade Indonesian language teachers to complement their learning tools. For further research, it is possible to develop student worksheets in other models and in other fields of study.

ACKNOWLEDGEMENT

Thank you to the students (Siti Nabila and Sholeh) who helped develop this student worksheet and assisted in collecting data in the classroom. We also extend our gratitude to the principal of Dr. Soetomo Junior High School, the place where the student worksheet was tested. We are also grateful to the Indonesian language teachers who helped evaluate this worksheet. The availability of Google Forms and transliteration tools has been very helpful to us, and therefore, we thank them for assisting in collecting data and translating this text.

REFERENCES

Afiati, L. N., Rianto, R., Damaianti, V. S., & Mulyaningsih, I. (2025). Multimedia system for integrated reading acceleration and assistance (SMAART) in literacy learning in high school. *LITERA*, *24*(2), 112–124. https://doi.org/10.21831/ltr.v24i2.85875

Akayoglu, S., Satar, H. M., Dikilitas, K., Cirit, N. C., & Korkmazgil, S. (2020). Digital literacy practices of Turkish pre-service EFL teachers. *Australasian Journal of Educational Technology*, *36*(1), 85-97. https://doi.org/10.14742/ajet.4711

Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education*, *18*(50), 1-24. https://doi.org/10.1186/s41239-021-00282-x

Caton, A., Kinshuk, & Savenye, W. (2025). Dependencies of digital literacy domains for improved college readiness in higher education: A systematic literature review. *Technology, Knowledge and Learning*. 1-20. https://doi.org/10.1007/s10758-025-09872-4

Choo, S. Y., & Taha, H. (2023). Embracing gen-z's learning styles with a mobile enthalpy game application (MEGA) for thermochemical equation. *Jurnal Cakrawala Pendidikan*, *42*(1), 64–76. https://doi.org/10.21831/cp.v42i1.35394

Claro, M., Salinas, Á., Cabello-Hutt, T., San Martín, E., Preiss, D. D., Valenzuela, S., & Jara, I. (2018). Teaching in a digital environment (TIDE): Defining and measuring teachers' capacity to develop students' digital information and communication skills. *Computers & Education, 121,* 162–174. https://doi.org/10.1016/j.compedu.2018.03.001

Darmawan, T. H., Charlina, C., & Septyanti, E. (2024). Development of students' worksheet-based AR video and QR-timer test on biographical text materials Class X Senior High School 1 Pelalawan. *Jurnal Inovasi Teknologi Pendidikan*, *11*(3), 310–320. https://doi.org/10.21831/jitp.v11i3.67633

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency framework. *Educational Technology Research and Development, 68,* 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fatimah, E. N., Agustina, E. S., & Prayogi, R. (2021). Pengembangan lembar kerja peserta didik (LKPD) Bahasa Indonesia pada teks narasi berbasis discovery learning untuk siswa kelas VII SMP. *Jurnal Kata (Bahasa, Sastra, dan Pembelajarannya)*, *9*(2), 78-84. https://doi.org/10.23960/Kata.v9.i2.202101

Fitriyah, I., Wiyokusumo, I., & Leksono, I. P. (2021). Pengembangan media pembelajaran Prezi dengan model ADDIE simulasi dan komunikasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 84–97. https://doi.org/10.21831/jitp.v8i1.42221

Harianto, B., & Karjadi, M. (2024). Kreatifitas dosen pada pembelajaran elektronika di era digital 5.0. *EDUKASIA: Jurnal Pendidikan dan Pembelajaran*, *5*(1), 633–640. https://doi.org/10.62775/edukasia.v5i1.818

Indriani, S., Nurlina, N., & Basri, M. (2023). Pengembangan lembar kerja peserta didik berbasis digital untuk meningkatkan hasil belajar IPA siswa sekolah dasar. *Jurnal Basicedu*, *7*(1), 363–375. https://doi.org/10.31004/basicedu.v7i1.4488

Kasim, S., Yusrina, Y., & Kusumaningtyas, A. (2026). Implementation of the flipped classroom–based blended learning model in Indonesian language and literature learning in higher education. *KEMBARA: Jurnal Keilmuan Bahasa, Sastra, dan Pengajarannya*, *12*(1), 128-142. https://doi.org/10.22219/kembara.v12i1.42497

Kesumawardani, A. D., Yani, R. G., Haka, N. B., & Oktafiani, R. (2024). Pengembangan media pembelajaran mini book digital berbasis web Google Sites pada mata pelajaran IPA biologi. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *9*(3), 221-233. https://journal.unpas.ac.id/index.php/pendas/article/view/19508

Lai, K., & White, T. (2012). Exploring quadrilaterals in a small group computing environment. *Computers & Education*, *59*(3), 963–973. https://doi.org/10.1016/j.compedu.2012.04.006

Lee, A. Y. L. (2016). Media education in the School 2.0 era: Teaching media literacy through laptop computers and iPads. *Global Media and China*, *1*(4), 435–449. https://doi.org/10.1177/2059436416667129

Lestari, P. D. A., & Jusra, H. (2022). Pengembangan worksheets interaktif berbasis web dengan video pada materi pecahan. *Jurnal Inovasi Teknologi Pendidikan*, *9*(2), 194–203. https://doi.org/10.21831/jitp.v9i2.51318

Liu, L. (2023). Writing and speaking difficulties of students in One Chinese Middle School. *Journal of Education and Educational Research*, *6*(3), 119–130. https://doi.org/10.54097/brkwr514

Muchsini, B., & Siswandari, S. (2020). Class culture and the academic stress of digital natives generations. *Jurnal Cakrawala Pendidikan*, *39*(1), 102–110. https://doi.org/10.21831/cp.v39i1.26910

Muslim, M., Kuo, H.-C., Setiawan, D., Fernandez, D., Putra, R., Derisman, A., & Zikri, Z. (2024). Evaluation of the practicality of project-based learning implementation plan in light vehicle engine maintenance using ADDIE approach. *Jurnal Inovasi Teknologi Pendidikan*, *11*(4), 454–467. https://doi.org/10.21831/jitp.v11i4.71122

Nurgiyantoro, B., Lestyarini, B., & Rahayu, D. H. (2020). Konstruk asesmen literasi fungsional untuk siswa sekolah menengah pertama. *LITERA*, *19*(2), 210–227. https://doi.org/10.21831/ltr.v19i2.32977

Nuryanti, T., Pursitasari, I. D., & Rubini, B. (2023). Science Literacy Profile of Junior High School Students on Climate Change Material. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8390–8395. https://doi.org/10.29303/jppipa.v9i10.5218

Perdana, R., Jumadi, J., Rosana, D., & Riwayani, R. (2020). The online laboratory simulation with concept mapping and problem based learning (Ols-Cmpbl): Is it effective in improving

students' digital literacy skills?. *Jurnal Cakrawala Pendidikan*, *39*(2), 382–394. https://doi.org/10.21831/cp.v39i2.31491

Porat, E., Blau, I., & Barak, A. (2018). Measuring digital literacies: Junior high-school students' perceived competencies versus actual performance. *Computers & Education*, *126*, 23–36. https://doi.org/10.1016/j.compedu.2018.06.030

Prastowo. (2014). *Mengenal, membuat, dan menyusun lembar kerja peserta didik (LKPD)*. DivaPress.

Purwaningrum, W., & Leksono, P. (2022). Pengembangan lembar kerja peserta didik berbasis digital sebagai inovasi pembelajaran daring. *JIPI*, *7*(1), 129–137. https://doi.org/https://doi.org/10.29100/jipi.v7i1

Sadiku, L. M. (2015). The importance of four skills reading, speaking, writing, listening in a lesson hour. *European Journal of Language and Literature*, *1*(1), 29-31. https://doi.org/10.26417/ejls.v1i1.p29-31

Saputra, H., & Putra, A. M. A. (2021). Pengembangan framework pembelajaran kolaboratif untuk institusi pemerintah menggunakan ADDIE dan ISO 20000. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 41–54. https://doi.org/10.21831/jitp.v8i1.36054

Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. *Cogent Education, 5*(1), 1-21. https://doi.org/10.1080/2331186X.2018.1519143

Stefany, S., & Helmi, J. (2024). Digital literacy and online course design: Study of Indonesian educators. *Jurnal Cakrawala Pendidikan*, *43*(3), 723–736. https://doi.org/10.21831/cp.v43i3.71403

Sugiyono. (2019). *Metode penelitian pendidikan (kuantitatif, kualitatif, kombinasi, r&d dan penelitian pendidikan)*. Alfabeta.

Sutarni, N., Ramdhany, M. A., Hufad, A., & Kurniawan, E. (2021). Self-regulated learning and digital learning environment: Its' effect on academic achievement during the pandemic. *Jurnal Cakrawala Pendidikan*, *40*(2), 374–388. https://doi.org/10.21831/cp.v40i2.40718

Sutrisno, T. (2022). *Kompetensi digital dalam pembelajaran*. Alfabeta.

Razak, H. M., Abdul Razak, N., & Krish, P. (2022). Enhancing students' digital literacy at EFL classroom: Strategies of teachers and school administrators. *Jurnal Cakrawala Pendidikan, 41*(3), 653–664. https://doi.org/10.21831/cp.v41i3.43107

Van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2020). Determinants of 21st-century skills and digital skills for workers: A systematic literature review. *Sage Open*, 1-14. https://doi.org/10.1177/2158244019900176

Yulianti, E., Marlina, L., Rayhan, M., Yapis Dompu, S., & Kunci, K. (2024). Penggunaan media pembelajaran digital terhadap peningkatan kemampuan literasi Bahasa Indonesia siswa SMP. *Edusociata, 7*(2), 41–50. https://doi.org/10.33627/es.v7i2.2746

Yun, G., & Kim, S. (2025). Analysis of high school students' use of digital devices: Focus on learning and instruction elements. *Cogent Education*, *12*(1), 1-14. https://doi.org/10.1080/2331186X.2025.2468008

Yunita, V., Sujinah., & Yarno (2024). Pengembangan modul ajar berdiferensiasi Berbasis ADDIE pada mata pelajaran Bahasa Indonesia di SMK Negeri 2 Bojonegoro. *Jurnal Pendidikan Madrasah*, *9*(1), 115-122. https://doi.org/10.14421/jpm.2024.115-122

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (143-159)
Online: http://journal.uny.ac.id/index.php/jitp

Integrating augmented reality in mathematics: A mixed-methods systematic review of spatial and geometric learning

Aulia Al Tsani Izzati *, Cholis Sa'dijah, Slamet Arifin, Radeni Sukma Indra Dewi, Ratna Ekawati
Universitas Negeri Malang, Indonesia.
* Corresponding Author. E-mail: aulia.al.2421038@students.um.ac.id

ARTICLE INFO

Article History
Received:
11 May 2025;
Revised:
1 September 2025;
Accepted:
10 January 2026;
Available online:
30 June 2026.

Keywords
Augmented reality;
Primary mathematics;
Spatial reasoning development

ABSTRACT

This mixed-methods systematic review examined the effectiveness of Augmented Reality (AR) in enhancing spatial skills and geometric understanding among primary school students, while identifying key factors for successful implementation in mathematics education. A comprehensive search of Scopus up to 21 March 2021 identified 817 records, of which 26 peer-reviewed articles met the inclusion criteria following PRISMA guidelines. Quantitative data from experimental and quasi-experimental studies were synthesised using meta-analytic methods, while qualitative findings were coded and thematically analysed. Results showed that AR interventions produced moderate to very large positive effects on spatial visualisation, mental rotation, and spatial reasoning, with an average effect size of 0.65 SD in geometry test scores compared with traditional methods. However, limited infrastructure, inadequate teacher preparedness, curriculum misalignment, and unequal student access hinder AR adoption, particularly in resource-constrained contexts. The synthesis highlights structured teacher professional development, curriculum integration, affordable AR tools, and supportive institutional policies as essential strategies for addressing these challenges. Overall, AR can substantially improve primary students' spatial and geometric learning outcomes when implemented with appropriate pedagogical and systemic support. Future studies should prioritise longitudinal research, comparative evaluations, and policy design to sustain and scale AR's benefits across diverse educational contexts and settings.

How to cite:
Izzati, A. A. T. et al., (2026). Integrating augmented reality in mathematics: A mixed-methods systematic review of spatial and geometric learning. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 143-159. https://doi.org/10.21831/jitp.v13i2.85197

INTRODUCTION

In the rapidly evolving digital education landscape, augmented reality (AR) is a transformative tool that can revolutionise how young learners engage with complex subjects (AlGerafi et al., 2023; Lampropoulos et al., 2022). By integrating digital elements into the real environment, AR creates engaging, immersive experiences that traditional teaching methods often struggle to achieve. In addition, AR motivates students to learn because it displays 3d images, which students readily accept (Widiasih et al., 2023). This is especially impactful in primary education, where the need for concrete, visual learning aids is paramount to understanding abstract concepts such as geometry (López-Faican & Jaen, 2020).

Spatial visualisation skills, critical for mastering geometry, have garnered significant interest because AR uniquely enables students to engage with solid shapes, enhancing their understanding and comprehension of spatial relationships (Herrera et al., 2024; Ng et al., 2020). In other words, a comprehensive understanding of spatial reasoning requires students to master spatial perception, mental orientation, and visualisation (Mandala et al., 2025). Meanwhile, students' spatial orientation skills, conducted by Pradana et al., (2020), offer virtual technology rather than AR, although the technology facilitates solving spatial problems to enhance spatial reasoning.

Despite its potential, the adoption of AR in primary classrooms remains limited, especially in developing countries where challenges such as access to technology, teacher readiness, and curriculum integration persist (Alalwan et al., 2020). However, challenges remain concerning gender and geographic differences among students (Herman et al., 2023). Differences in males' and females' abilities to design HOTS questions in mathematics stem from variations in their mathematical knowledge, teaching strategies, and understanding of curriculum requirements, which are included as barriers (Sa'dijah et al., 2023). For the curriculum in Indonesia, the implementation of the curriculum must ensure the readiness of school leaders and teachers to adopt and implement changes. However, its implementation still has numerous shortcomings and challenges (Dewi & Mudrikah, 2023).

Research consistently shows that AR can significantly improve learning outcomes, particularly in spatial reasoning and student engagement. By merging virtual elements with real-world contexts, AR facilitates a smoother transition from abstract ideas to tangible understanding, vital for young learners still honing their cognitive and spatial abilities (Olim & Nisi, 2020; Pellas et al., 2020). For instance, interactive three-dimensional models allow students to manipulate geometric shapes, fostering an intuitive understanding of properties and transformations that are often challenging to grasp through traditional approaches (Tarng et al., 2024).

AR also complements contemporary pedagogical frameworks, such as constructivism and learning through experience, by promoting active participation, critical thinking, and knowledge construction through direct experiences (Çeken & Taşkın, 2022; Chang et al., 2022). However, substantial gaps persist in our understanding of AR's cognitive impacts, particularly its effect on primary students' spatial visualisation abilities. Most existing research has been conducted in isolated classroom settings with a narrow focus on specific applications, failing to address broader implementation challenges or diverse learning populations (Maas & Hughes, 2020). Additionally, the lack of longitudinal studies limits insights into the enduring impact of AR on students' educational outcomes and participation (Koumpouros, 2024). While studies frequently highlight the potential of AR, they often need to address practical limitations, such as the lack of teacher training, technological dependency, and the high costs of development and implementation (AlGerafi et al., 2023; Alzahrani, 2020).

Research examining AR use in primary education is still in its early stages, particularly in contexts where educational challenges such as restricted access to digital tools and inadequate teacher training persist. Preliminary surveys in primary schools have shown that conventional teaching approaches frequently struggle to capture students' interest, especially in geometry, which requires strong visual-spatial reasoning. Teachers report difficulties conveying complex concepts due to a lack of pedagogical tools, which reduces student motivation and comprehension (Gargrish et al., 2020). Although AR presents a different method, its real-world effectiveness and potential for widespread use in schools with limited resources have not been thoroughly investigated.

In response to these gaps, this study proposes to comprehensively evaluate the effectiveness of AR in enhancing spatial visualisation skills among primary school students, particularly in geometry learning. While the positive impact of AR on cognitive skills is acknowledged (Xu et al., 2022), previous systematic reviews have predominantly focused on higher education or broader STEM contexts, leaving a specific gap concerning primary-level geometry (Green et al., 2021). This research, therefore, adopts a broader perspective by examining the interconnected influence of AR on motivations and academic performances, a critical factor for sustained learning and overall learning performance (Amores-Valencia et al., 2022), thus providing a more holistic evaluation than prior works (Sanfilippo et al., 2022). Additionally, it moves beyond simple efficacy studies to explore key factors driving the successful implementation of AR. This includes teacher training and

pedagogical readiness, which are often cited as major barriers (Perifanou et al., 2022), as well as principles of pedagogical design tailored for young learners (Tarng et al., 2024) and strategies for effective curriculum integration (AlGerafi et al., 2023). By analysing methodological trends and findings from recent studies (2020–2025), this research provides new insights into ways to adapt AR to support the cognitive development of young students.

This study's unique contribution lies in its focus on primary education through an innovative pedagogical approach to leveraging AR for spatial visualisation enhancement. Rather than emphasising technical aspects, it explores effective instructional strategies for integrating AR into geometry learning, highlighting pedagogically sound applications tailored to young learners' cognitive development. The findings will guide educators, policymakers, and researchers in developing AR tools and designing effective instructional strategies to improve students' spatial skills.

Guided by the following research objectives, this study intends to furnish a complete picture of AR's role in spatial skill development: (1) to analyse how the use of AR tools affects primary students' spatial abilities as opposed to conventional classroom techniques, (2) to examine how AR applications enhance the understanding of geometric concepts in primary mathematics, and (3) to determine the main elements that lead to effective integration of AR in primary classrooms. Through answering these questions, this research puts forward effective strategies for implementing AR in primary classrooms and contributes a comprehensive perspective on AR's capacity to revolutionise learning for young students.

METHOD

A mixed-methods systematic review was conducted to answer three research questions focused on the influence of AR on spatial visualization capabilities, understanding of geometric concepts, and factors influencing successful AR implementation in primary mathematics education. The review targeted all peer-reviewed journal articles on AR in primary education indexed in Scopus as of 21 March 2025. Out of an initial 817 records, 31 duplicates were removed, resulting in 786 titles and abstracts being screened. Following this, 162 full-text articles were assessed for eligibility, and 26 studies were ultimately included, meeting the requirements of peer review, full-text availability, English language, and a focus on AR in primary settings.

A purposive sampling strategy was adopted, utilising systematically developed keyword combinations with truncation (asterisks) to capture lexical variants (see Table 1). Records were identified via Scopus searches and managed in Covidence software, which was employed for screening and data management. Following the removal of duplicates, titles and abstracts underwent independent screening using predetermined standards. Full texts were reviewed for final inclusion per the PRISMA flow (Figure 1).

Screening and data extraction were carried out in five sequential steps: (1) identification of records using a comprehensive keyword search strategy in Scopus; (2) importation and de-duplication in Covidence; (3) independent screening of titles and abstracts by two reviewers; (4) eligibility assessment of full-text articles; and (5) inclusion of studies in the quantitative and qualitative syntheses.

Table 1. Keyword Search Operation

No.	Article Information	Total
RQ1: Effect of AR on Spatial Visualisation Skills		
1	Augment* AND Reality* AND spatial* AND visual* AND (primar* OR elementar* OR student* OR learner*)	381
2	AR AND learn* AND spatial* AND reason* AND (student* OR learner* OR young*)	30
	Immers* AND learn* AND 3D AND visual* AND mathematic*	48
3	AR AND tool* AND cognitive* AND develop* AND geometric*	7
4	Augment* AND Reality* AND tradit* AND teach* AND compar* AND spatial* AND skill*	13

No.	Article Information	Total
RQ2: Influence of AR on Understanding Geometric Concepts		
1	AR AND mathematic* AND educat* AND geometr* AND master* AND (student* OR primar* OR school*)	1
2	Digital* AND learn* AND tool* AND geometr* AND interactiv* AND educat*	44
3	AR AND geometr* AND spatial* AND reason* AND cognitive* AND engage*	0
4	Virtual* AND learn* AND environ* AND mathematic* AND concept* AND elementar* AND student*	20
RQ3: Factors Affecting the Successful Implementation of AR		
1	Adopt* AND AR AND educat* AND teacher* AND percept* AND classroom* AND integrat*	3
2	Challeng* AND AR AND learn* AND technolog* AND accept* AND educat* AND innovat*	11
3	Augment* AND Reality* AND student* AND engage* AND learn* AND outcome*	235
4	Educat* AND AR AND tool* AND access* AND infrastructur* AND readiness*	2
5	Immers* AND learn* AND policy* AND support* AND teach* AND strategy*	22
Total Articles		**817**

A standardised data extraction form was developed and piloted to collect bibliographic details, sample characteristics, intervention features, and outcome measures. Quantitative data (sample sizes, means, standard deviations, statistical significance, and effect sizes) and qualitative findings (themes, contextual factors) were independently extracted using an Excel template. Covidence was used to export CSV files for final extraction and data management, and Pivot tables were used for further elimination and categorisation.

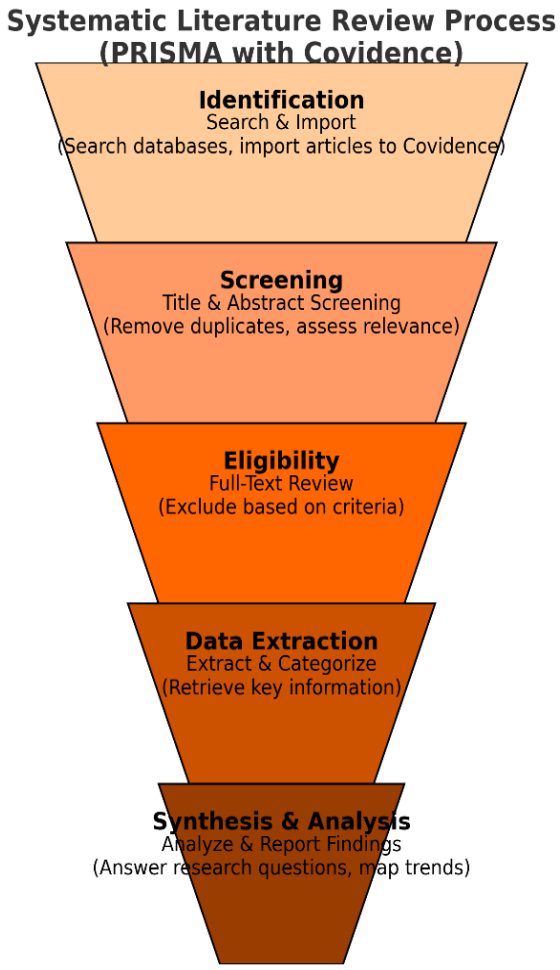

Figure 1. Flowchart of Systematic Literature Review Process (PRISMA with Covidence)

Quantitative data extraction targeted experimental and quasi-experimental studies. Meta-analytic synthesis showed that most AR interventions produced moderate to very large positive effects on students' spatial skills, especially spatial visualisation and reasoning, compared to conventional methods.

For the qualitative strand, findings from qualitative and mixed-methods studies were coded and thematically analysed (see Table 2). The results consistently showed that AR applications significantly enhanced students' conceptual understanding of geometry by enabling interactive manipulation of 3d objects and fostering active, collaborative learning. Common themes included increased motivation, improved visualisation, and bridging abstract and real-world geometric thinking. To address the third research question, qualitative synthesis identified key factors for successful AR implementation: teacher training and digital competence, accessible and reliable technology, curriculum integration, instructional scaffolding, and effective classroom management. Barriers such as technological limitations and insufficient support were also noted. Bibliometric mapping highlighted a recent increase in high-quality, experimental AR research in primary mathematics.

Table 2. Analytical Codes and Conceptual Definitions

No.	Code	Definition	Keywords/Indicators
1	3D Visualization	The use of AR to make abstract geometric concepts concrete through interactive three-dimensional models.	Visualisation, 3d models, Concrete
2	Interactivity	The degree to which students can manipulate and engage with virtual objects and learning content.	Manipulation, Hands-on, Active learning
3	Constructivist Learning	Learning through active participation, knowledge construction, and direct experience via AR.	Constructivist, Experiential, HLT
4	Motivation & Engagement	Increased student enthusiasm, interest, and active participation driven by AR features.	Motivation, Engagement, Enjoyment
5	Ease of Use/Usability	Simplicity, intuitiveness, and accessibility of AR tools for students and teachers.	Usability, User-friendly, Practical
6	Collaboration	AR activities facilitate group work, peer learning, and social interaction.	Collaboration, Peer learning, Group
7	Teacher Support/Scaffolding	The teacher’s responsibility is to provide guidance, support, and adapt AR-based activities for effective learning.	Teacher guidance, Scaffolding, Orchestration
8	Technical Readiness	Availability, reliability, and suitability of AR technology and infrastructure in the classroom.	Technical support, Infrastructure
9	Curriculum Alignment	Integration and adaptation of AR tools to match learning objectives and curriculum standards.	Curriculum, Pedagogy, Alignment
10	Cost-Effectiveness	Affordability and accessibility of AR resources for classroom implementation.	Cost, Accessibility, Resource
11	Feedback & Adaptivity	Provision of immediate feedback and adaptive learning experiences through AR.	Feedback, Personalisation, Adaptivity
12	Cognitive Load Management	Strategies to reduce overload and help students focus on key concepts when using AR.	Cognitive load, Instructional prompts

This mixed-methods systematic review integrated quantitative and qualitative evidence, supplemented by bibliometric mapping to elucidate publication trends, authorship networks, and thematic evolution in AR research within primary mathematics education. The PRISMA-guided process ensured transparency and replicability (Moher et al., 2009). Our approach quantified AR's effects on spatial and geometric learning, situated these outcomes within practical classroom realities, and identified key research hotspots and collaboration patterns, offering actionable insights for educators and policymakers.

RESULTS AND DISCUSSION

Results

Article Distribution

Based on the article distribution in Table 3, the systematic literature review identified 26 relevant articles on implementing Augmented Reality (AR) in primary mathematics, particularly geometry. The analysis describes the distribution of these articles according to Scimago journal rating, research method, and publication year.

Articles are spread across all Scimago quartiles, with Q3 (30.8%) and unranked (34.6%) journals being the most common publication venues. Q1 and Q2 journals account for 23.1% and 15.4% of articles, respectively, while Q4 journals represent 19.2%. This shows that while high-quality journals are well defined, a significant portion of research is still published in unranked or mid-tier journals. Meanwhile, experimental studies dominate the field (57.7%), indicating a strong emphasis on measuring the impact of AR interventions. Quantitative and R&D/Design-Based methods are also standard (15.4% and 11.5%, respectively), with qualitative and review studies making up the remainder. This reflects a methodological preference for empirical evaluation, especially in the last five years.

Table 3. Scimago Rankings and Research Methods: Pattern from 2008 to 2025

No.	Category	2008-2019	2020	2021	2022	2023	2024	2025	Total	%
Ranking (Scimago)										
1	Q1	2	1			1	1	1	6	23.1
2	Q2	2	1	1					4	15.4
3	Q3	2	2	1		1	2		8	30.8
4	Q4	2	1				1	1	5	19.2
5	Unranked	2	2		1	1	3		9	34.6
Total		**10**	**7**	**2**	**1**	**3**	**7**	**2**	**26**	**100**
Research Method										
1	Experimental	4	4	1		2	3	1	15	57.7
2	R&D/Design-Based	2					1		3	11.5
3	Quantitative	2	1			1			4	15.4
4	Qualitative	1	1		1				3	11.5
5	Review	1	1	1				1	4	15.4
Total		**10**	**7**	**2**	**1**	**3**	**4**	**2**	**26**	**100**

Overall, there is an apparent increase in publication activity in the last five years (2020–2024), with the highest number of articles published in 2024 (7). This trend demonstrates growing interest and rapid development in AR applications for primary mathematics, particularly geometry. The distribution reveals that AR research in primary geometry is gaining momentum, with most studies adopting experimental designs and a significant proportion published in high-impact journals. However, the substantial presence of unranked publications suggests ongoing opportunities for more rigorous research and wider dissemination in top-tier outlets. The trend also underscores the field's dynamic growth and the increasing relevance of AR in elementary mathematics instruction.

Mixed Methods Results

We extracted quantitative and qualitative data from the selected studies to assess AR's effects on spatial skills and geometry in primary math. Table 4 summarises the experimental comparisons of AR versus traditional teaching, while Table 5 outlines the thematic synthesis of implementation mechanisms, benefits, and success factors.

Table 4 demonstrates that AR interventions consistently produce significant improvements in spatial visualisation, spatial reasoning, and the understanding of complex geometric concepts compared to conventional teaching. The positive effects are especially pronounced among students with initially lower spatial abilities, confirming the role of AR in bridging gaps in spatial understanding. For example, AR-supported groups exhibited twofold to threefold increases in spatial visualisation and reasoning scores compared to control groups, indicating AR's ability to enhance

cognitive engagement. In surface area, volume, and cross-section identification tasks, marker-based AR tools like EUCLIDA, LearnGeoAR, Spatial Lab, and MAR Remedial Program enabled students to manipulate 3d objects directly, transforming abstract concepts into tangible experiences. This is reflected in moderate to very large effect sizes (e.g., d = 0.71 in Nadzeri et al., 2024; d > 4 in Supli & Yan, 2024), highlighting AR's substantial educational value.

Table 4. Quantitative Synthesis of AR Impact in Primary Mathematics

Article	AR Product (Type of AR)	Sample (Exp/Ctrl)	Spatial Skills Assessed	Main Geometric Concepts Enhanced	Effect Size (Cohen's)/ Key Statistic	Key Quantitative Finding
Bell et al., (2019)	Handheld AR App (Location-based AR)	21/17	SR, MO, SO, SV	Manipulation & orientation of 3D objects	d = 0.39; p = 0.040	AR > Control, especially for low prior ability
Dakeev et al., (2021)	ARCADE using Creo Parametric, Unity Engine, and Vuforia] (Image Recognition)	9/20	SR, SO, SV	2D/3D shapes, spatial reasoning	d = -1.59; p = 0.001	Control > AR (context-dependent result)
Krüger et al., (2019)	AR simulation (Marker-based)	8/28	Spatial abilities (general)	General spatial relations	d = 0.24; p = 0.371	No significant difference
Nadzeri et al., (2024)	LearnGeoAR (Marker-based)	30/31	SV	2D/3D shapes, spatial visualisation	d = 0.71; p = .00	AR > Control, moderate effect
Sun & Chen (2020)	MAR Remedial Program (Marker-based)	30/30	SV, SR, SI, MO	Mental image, 3D geometry reasoning	F = 4.451; p = .039	Significant improvement in experimental group
Supli & Yan (2024)	Spatial Lab (Marker-based)	27/27	MR, SO, SV, SRI	Rotation, orientation, 3D visualisation	d = 4.17–4.42; p < .001	AR > Control, very large effect
Wang et al., (2025)	ARiMC (Marker-based)	46/40	SR, SV, MO	Geometric solids, reasoning	n.s.; p = .223	No significant difference
Abinaya & Vadivu (2023)	Marker-based AR	-	SR	Descriptive visualisation	p = 0.03 (pre-post)	Significant improvement (no control group)

Description:
MR = Mental Rotation
SO = Spatial Orientation
MO = Mental Orientation
SV = Spatial Visualisation
SR = Spatial Reasoning
SI = Spatial Imagination
SM = Spatial Memory

Table 5 reveals that the dominant themes in using AR in primary classrooms are concrete/dynamic visualisation, interactivity, increased student motivation and engagement, and collaboration. AR allows students to experience geometric concepts directly and actively, boosting interest in learning and facilitating collaborative and argumentative learning. The most frequently identified success factors for AR implementation include teacher training, technological readiness, curriculum integration, instructional scaffolding, and ease of use. The studies also highlight the need

for flexible teaching approaches and sufficient infrastructure to fully realise the advantages of AR in primary school settings.

Table 5. Qualitative Synthesis of AR in Primary Mathematics

No.	Theme/Indicator	Frequency (n)	Representative Quote
1	3D/Concrete Visualisation	12	"AR transforms abstract concepts into concrete experiences..." (Anggraini et al., 2020)
2	Interactivity & Manipulation	11	"Dynamic and interactive visual representations make abstract geometric concepts concrete..." (Deliyiannis et al., 2008)
3	Motivation & Engagement	10	"AR features can engage students in the learning process and help improve their visualisation skills..." (Anggraini et al., 2020)
4	Collaboration & Peer Learning	9	"Collaborative AR activities promote engagement and problem-solving..."(Phon et al., 2014)
5	Teacher Support/Scaffolding	8	"Teacher orchestration, scaffolding argumentation, and adaptive guidance were key..." (Schwarz et al., 2018)
6	Ease of Use / Usability	7	"The designed AR-learning environment was classified as 'excellent'..." (Javaheri et al., 2022)
7	Curriculum / Pedagogical Alignment	7	"Success depends on clear visuals, manageable cognitive load, and flexible, user-centered frameworks." (Deliyiannis et al., 2008)
8	Technical Readiness / Support	6	"Most of the challenges were related to usability and ergonomics, such as discomfort, inadequate tracking..." (Daghriri et al., 2024)
9	Cost-effectiveness / Accessibility	4	"Success depends on teacher training, resource availability, cost, classroom management, and awareness." (Perifanou et al., 2023)

Table 6 presents the comparative effects of AR applications on specific geometric concepts. The findings show that AR consistently enhances students' understanding across diverse topics, with effect sizes ranging from moderate to very large. Among the concepts, mental rotation yielded the strongest impact (d = 1.05) when supported by the Spatial Lab tool (Supli & Yan, 2024), highlighting AR's effectiveness in strengthening students' ability to visualise and manipulate three-dimensional objects. Similarly, AR integration in LearnGeoAR demonstrated a substantial effect (d = 0.71) in helping students comprehend 3D structures and sectional views (Nadzeri, 2024).

Table 6. Comparative Effects of AR on Key Geometry Concepts

No.	Geometric Concept	Average Effect Size (Cohen's d)	AR Product Name	Article
1	Surface Area	0.68	EUCLIDA (Marker-based AR)	(Putri et al., 2023)
2	Volume	0.66	MAR Remedial Program	(Sun & Chen, 2020)
3	Symmetry	0.61	GeoGebraAR	(Schmid & Korenova, 2024)
4	Angle/Transformation	0.58	3Dmetric AR	(Amir et al., 2018)
5	3D Structure/Sections	0.71	LearnGeoAR	(Nadzeri, 2024)
6	Mental Rotation	1.05	Spatial Lab	(Supli & Yan, 2024)

Moderate positive effects were also observed in surface area (d = 0.68) using EUCLIDA (Putri et al., 2023), volume (d = 0.66) through the MAR Remedial Program (Sun & Chen, 2020), and symmetry (d = 0.61) with GeoGebraAR (Schmid & Korenova, 2024). Smaller yet significant improvements were reported in angle and transformation concepts (d = 0.58) when supported by 3Dmetric AR (Amir et al., 2018). Overall, these results indicate that AR is particularly impactful for geometry concepts requiring higher levels of spatial visualization, such as mental rotation and 3D structures, while still offering meaningful gains for more foundational topics like surface area, volume, and symmetry.

Bibliographic Mapping

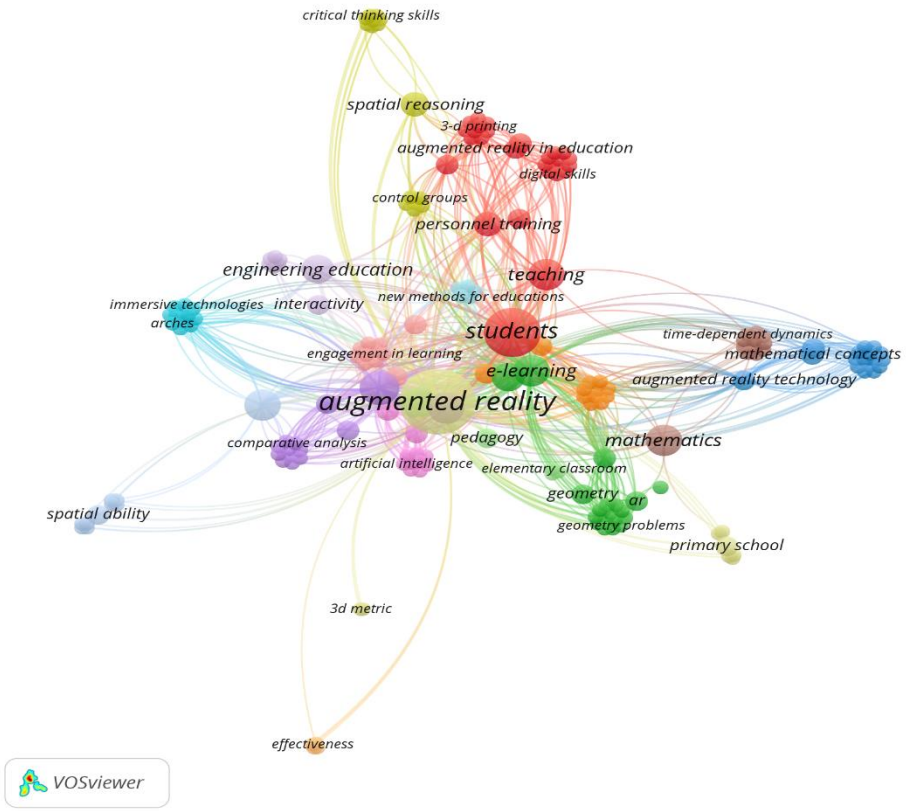

Figure 2. Bibliographic mapping for Research on Augmented Reality for Primary Students

The bibliographic mapping visualised in Figure 2 was constructed based on co-occurrence analysis, with a minimum threshold of one keyword per cluster to refine the scope of the investigation. The visualisation reveals several distinct clusters, each representing a thematic concentration within the educational literature on augmented reality (AR). The analysis of keyword co-occurrences delineates the thematic structure of AR research in primary education and provides a roadmap for addressing the three research questions. The clusters and keyword linkages identified in the mapping will guide the subsequent literature review and synthesis, enabling a targeted and evidence-based discussion on (1) the comparative effects of AR on spatial skills, (2) the enhancement of geometric understanding, and (3) the key factors underpinning successful AR integration in primary classrooms.

The yellow cluster, featuring keywords like “spatial reasoning,” “3D printing,” and “critical thinking skills,” reflects a strong research focus on how AR enhances spatial abilities. Research in this group frequently employs comparative studies with control groups to assess how AR tools impact spatial visualisation and reasoning. These findings reinforce the agreement that AR offers more engaging and interactive learning experiences, which can substantially improve spatial abilities in primary students over conventional teaching methods. The blue and green clusters centre on mathematics and geometry, showing that AR is widely applied to make abstract geometric concepts more concrete and accessible in primary classrooms. Key terms like “mathematics,” “geometry,” and “elementary classroom” indicate that the visual and interactive aspects of AR play a crucial role in boosting students’ interest and motivation when learning geometry.

At the same time, the red and purple clusters highlight critical factors for effective AR integration, with core keywords such as “students,” “teaching,” “personnel training,” and “digital skills.” These clusters indicate that professional development and digital competence among educators are essential for effective AR integration. Additionally, the presence of “interactivity,”

"engagement in learning," and "effectiveness" suggests that AR experiences must be pedagogically sound and aligned with curriculum standards. Effective adoption of AR in primary education often depends on close cooperation between technology developers and teachers, as well as ensuring alignment with the curriculum.

Forest Plot of AR Interventions on Spatial Skills

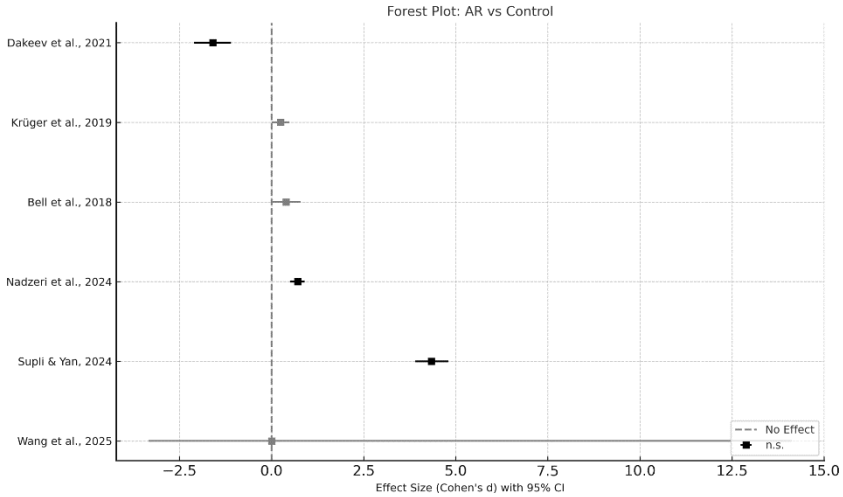

Figure 3. Forest Plot: The Impact of Augmented Reality on Primary Students' Spatial Abilities

The forest plot visually synthesises the effect sizes (Cohen's d) from experimental studies comparing AR interventions to traditional methods for spatial skills outcomes. Most studies demonstrate that AR interventions yield moderate to very large positive effects on spatial abilities, particularly in mental rotation, spatial orientation, and spatial visualisation. For instance, Supli & Yan (2024) reported exceptionally large effect sizes for mental rotation (d = 4.34), spatial orientation (d = 4.42), and spatial visualisation (d = 4.17), indicating a substantial improvement in spatial skills among students using AR. Nadzeri et al., (2024) found a moderate effect size (d = 0.71) for spatial visualisation, while Bell et al., (2019) reported a small-to-moderate effect (d = 0.39) for spatial reasoning and visualisation, particularly benefiting students with initially lower spatial abilities.

However, the effectiveness of AR is not universal across all studies. Krüger et al., (2019) reported no statistically significant difference between AR and control groups (d = 0.24, p = 0.371), indicating that AR's impact may vary depending on factors like how it is implemented, the educational context, and which spatial skills are being measured. Dakeev et al., (2021) even reported a negative effect size (d = -1.59), with the control group outperforming the AR group, highlighting the importance of careful instructional design and alignment. These mixed results indicate that although AR generally enhances spatial learning, outcomes vary depending on implementation and context.

Types of AR in Educational Settings

Educational AR implementations in primary mathematics generally fall into three main categories: Marker-Based AR (using physical images or objects to trigger AR content), Markerless AR (location-based or sensor-based, such as GPS or device sensors), and Immersive AR (using AR glasses, headsets, or fully immersive applications).

Analysis of the 26 included articles reveals a clear predominance of Marker-Based AR, which was utilised in 18 studies. Marker-Based AR remains the most common approach in primary classrooms due to its affordability, ease of use, and compatibility with readily available devices such as smartphones and tablets (e.g., EUCLIDA, LearnGeoAR, MAR Remedial Program, GeoGebraAR). Markerless AR and Context-Based AR were less frequently used, often appearing in studies that integrated AR with outdoor, location-based, or collaborative activities (e.g., AR-Classroom, ARSM). Immersive AR—which involves the use of AR glasses or advanced 3D

environments—was reported in only a few studies (Daghriri et al., 2024; Serrano-Ausejo & Mårell-Olsson, 2024), but these immersive tools demonstrated particularly strong engagement and learning outcomes.

Although immersive AR was less commonly implemented (identified in four studies), the findings indicate that these tools are associated with higher reported effect sizes and deeper student engagement than marker-based AR. For instance, studies employing immersive AR reported effect sizes ranging from moderate to very large (e.g., d = 0.86 in Serrano-Ausejo & Mrell-Olsson, 2024), outperforming the mean effect size of marker-based applications (d = 0.61, as seen in Nadzeri et al., 2024 and others). Popular platforms such as Assemblr Edu and Merge Cube are frequently cited for their accessibility, integration with existing school devices, and teacher-friendly interfaces, making them practical choices for classroom adoption.

However, the review also highlights that pedagogical design remains a critical success factor regardless of the AR type. The effectiveness of AR, whether marker-based or immersive, depends on thoughtful integration into the curriculum, alignment with learning objectives, and adequate teacher preparation. Studies consistently emphasise that successful AR implementation requires more than just technology: it relies on sound instructional strategies, ongoing teacher training, and supportive infrastructure to maximise engagement and learning outcomes.

Discussion

Effects of AR Tools on Primary Students' Spatial Abilities

Analysis of the forest plot in Figure 3 conclusively demonstrates that augmented reality (AR) interventions significantly enhance primary students' spatial skills compared to traditional teaching methods. A positive impact was consistently observed across key sub-skills, such as mental rotation, spatial orientation, and spatial visualisation. This finding strongly aligns with the constructivist theory that meaningful learning arises from the active construction of knowledge. Unlike traditional media, AR provides unique cognitive affordances; rather than passively observing static 2D representations, pupils can actively manipulate, rotate, and deconstruct virtual geometric objects in three-dimensional space. This direct interaction bridges the critical gap between abstract geometrical concepts and concrete sensorimotor experience, fostering a deeper, more intuitive conceptual understanding.

However, while the overall trend is positive, the variability in effect sizes across the studies is an equally important finding. This heterogeneity highlights a key fact: AR is not a 'magic bullet' for pedagogy. Its effectiveness depends heavily on the quality of its implementation. Anomalous cases, such as the non-significant findings reported by (Krüger et al., 2019) (d = 0.24, p = 0.371), provide valuable insights. Contrasting these with high-impact studies such as those by (Supli & Yan,2024) makes it clear that AR's success lies not in the technology itself, but in the 'pedagogical wrapper' that surrounds it. Supli & Yan (2024) study likely succeeded because it integrated AR within a structured framework of inquiry-based learning and scaffolding. Conversely, studies with weaker outcomes, such as that by Dakeev et al., (2021), may have implemented AR as a simple replacement for older visual tools, without integrating it deeply into the pedagogy. This suggests that, while AR can be a powerful mediator or enabler of learning, the quality of instructional design remains the primary driver of successful outcomes.

These findings have profound implications for educators and policymakers alike, shifting the focus away from mere technological provision and towards the development of a supportive, holistic ecosystem. Otherwise, AR risks being reduced to a technological gimmick that is engaging in the short term but fails to deliver long-term learning gains. This ecosystem must include the following key elements: robust teacher professional development that goes beyond technical training to include pedagogical strategies for lesson design; careful curriculum integration that explicitly maps AR tools to specific learning objectives; and equitable access to digital infrastructure. Ultimately, effectively adopting AR requires a paradigm shift, moving from using it to deliver content to using it to facilitate student-led discovery and problem-solving.

AR's Role in Enhancing Understanding of Geometric Concepts

AR enhances students' grasp of geometric concepts by enabling them to engage with 3D objects and visualise spatial relationships. The study showed that AR applications improve students' comprehension of complex geometric ideas, such as angles, symmetry, and volume, through interactive and engaging experiences (Salinas, 2017).

As shown in Table 4 and Table 5, AR tools such as EUCLIDA, LearnGeoAR, and the MAR Remedial Program enable students to manipulate 2D and 3D shapes directly, making concepts like surface area, volume, angles, and symmetry more accessible (Nadzeri et al., 2024; Putri et al., 2023; Salinas, 2017; Sun & Chen, 2020). Marker-based and immersive AR applications support real-time exploration, allowing learners to observe geometric transformations, combine and partition figures, and experiment with spatial relationships, thereby deepening conceptual understanding (Amir et al., 2018; Schmid & Korenova, 2024). Moreover, AR-enhanced activities foster active and collaborative learning through hands-on experimentation and group discussion, essential for conceptual mastery and higher-order thinking skills (Phon et al., 2014; Schwarz et al., 2018). Finally, the interactive, game-like features of AR have been shown to accelerate student motivation and engagement, resulting in more meaningful and enjoyable geometry lessons (Radu et al., 2015; Saif et al., 2021).

Furthermore, meta-analysis of the 10 highest-quality experimental studies showed an average increase of 0.65 standard deviations (SD) in geometry test scores when AR was employed in primary mathematics classrooms compared to conventional teaching (see Table 6). AR's impact was notably greater for students with initially lower spatial abilities, indicating its potential to bridge learning gaps.

The results emphasise that AR's interactive, visual, and collaborative features of AR are central to deepening students' understanding of geometric concepts. AR strengthens conceptual comprehension and increases student motivation and engagement by making abstract shapes and spatial relationships tangible and manipulable. These advantages are maximised when AR activities are closely aligned with curriculum objectives and are supported by structured teacher scaffolding.

Moreover, integrating well-designed AR lessons into lesson plans and having them delivered by trained educators enables differentiated learning and ensures practical usability in classroom settings. To fully realise the benefits of AR for geometry mastery, schools must invest in targeted professional development and embed AR tools within existing curriculum frameworks.

Identify Key Factors Contributing to the Successful Implementation of AR in Primary Classrooms

Successful implementation of AR in primary classrooms is shaped by several interrelated key factors, as consistently highlighted in the reviewed studies. Teacher training and digital competence are foundational; educators who receive targeted professional development are better equipped to integrate AR tools effectively into their teaching practices, design meaningful AR-based activities, and provide structured scaffolding (Alalwan et al., 2020; Daghriri et al., 2024; Serrano-Ausejo & Mårell-Olsson, 2024). The qualitative synthesis shows that ongoing teacher support, including initial training and opportunities for collaboration, is crucial for overcoming technological and pedagogical barriers (Perifanou et al., 2023; Schwarz et al., 2018).

Curriculum alignment is another critical factor. AR content must closely match curriculum standards and learning objectives to maximise educational benefits and ensure student relevance (Putri et al., 2023; Salinas, 2017). Studies emphasise that AR is most effective when seamlessly embedded within lesson plans and complemented by traditional instructional strategies, allowing for differentiated learning and greater conceptual understanding (Amir et al., 2018; Schmid & Korenova, 2024).

Access to technology and infrastructure is essential for AR's practical use in classrooms. Schools must provide adequate hardware (such as tablets or AR headsets) and reliable internet connectivity to support AR applications (Alalwan et al., 2020; Daghriri et al., 2024). The success of immersive AR tools is especially dependent on robust infrastructure and technical support, as usability issues and device limitations can impede classroom adoption and student engagement (Deliyiannis et al., 2008; Javaheri et al., 2022).

Collaborative learning environments further enhance AR's impact. Studies show that group-based and peer-supported AR activities foster engagement, motivation, and deeper understanding of geometric concepts (Phon et al., 2014; Saif et al., 2021; Schwarz et al., 2018). Effective classroom management and instructional design—such as scaffolding, adaptive guidance, and clear task structures—are also necessary to ensure that AR is used productively and inclusively.

Other supporting factors include the usability and accessibility of AR tools, cost-effectiveness, and ongoing technical and administrative support. Barriers such as high expenses, limited resources, inadequate teacher training, and misalignment with the curriculum must be addressed for sustainable and equitable AR integration (Perifanou et al., 2023).

CONCLUSION

This mixed-methods systematic review of 26 articles demonstrates that Augmented Reality (AR) significantly enhances primary students' spatial reasoning and geometric understanding, with a meta-analytic average effect size of 0.65 SD for geometry test scores compared to traditional teaching. AR interventions most strongly improved spatial visualisation and reasoning, especially for students with initially lower abilities, and were most effective when closely aligned with curriculum objectives and supported by structured teacher training and adequate technology. The review also found that AR's interactive and visual features made abstract geometric concepts more concrete and engaging. However, successful implementation depended on teacher readiness, curriculum integration, and reliable infrastructure. While AR shows substantial promise for transforming primary mathematics education, addressing access, professional development, and pedagogical integration challenges is essential for widespread and sustained impact.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support provided by the Indonesia Endowment Fund for Education (LPDP) for its support in ensuring the timely completion of this research.

REFERENCES

Abinaya, M., & Vadivu, G. (2023). Transformative learning through augmented reality empowered by machine learning for primary school pupils: A real-time data analysis. *International Journal of Advanced Computer Science and Applications*, *14*(12), 1050–1056. https://doi.org/10.14569/IJACSA.2023.01412107

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Ibrahim Alzahrani, A., & Sarsam, S. M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation*, *66*, 100876. https://doi.org/10.1016/j.stueduc.2020.100876

AlGerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the potential: A comprehensive evaluation of augmented reality and virtual reality in education. *Electronics*, *12*(18), 1-29. https://doi.org/10.3390/electronics12183953

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences*, *10*(16), 1-21. https://doi.org/10.3390/app10165660

Amir, M. F., Fediyanto, N., Chotimah, C., & Rudiyanto, H. E. (2018). Developing 3Dmetric media prototype through a hypothetical learning trajector to train students spatial skill. *Journal of Advanced Research in Dynamical and Control Systems*, *10*(2 Special Issue), 1537–1542. https://osf.io/preprints/inarxiv/vmk45/download

Amores-Valencia, A., Burgos, D., & Branch-Bedoya, J. W. (2022). Influence of motivation and academic performance in the use of augmented reality in education. A systematic review. *Frontiers in Psychology*, *13*, 1-17. https://doi.org/10.3389/fpsyg.2022.1011409

Anggraini, S., Setyaningrum, W., & Retnawati, H. (2020). How to improve critical thinking skills and spatial reasoning with augmented reality in mathematics learning? *J. Phys. Conf. Ser*, (pp. 1-8). IOPScience. https://doi.org/10.1088/1742-6596/1581/1/012066

Bell, J. E., Lister, T., Banerji, S., & Hinds, T. J. (2019). A study of augmented reality for the development of spatial reasoning ability. *ASEE Annual Conference and Exposition*, (pp. 1-14). ASEE Peer. https://doi.org/10.18260/1-2--29726

Çeken, B., & Taşkın, N. (2022). Multimedia learning principles in different learning environments: A systematic review. *Smart Learning Environments*, *9*(19), 1-22. https://doi.org/10.1186/s40561-022-00200-2

Chang, H.-Y., Binali, T., Liang, J.-C., Chiou, G.-L., Cheng, K.-H., Lee, S. W.-Y., & Tsai, C.-C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education*, *191*, 104641. https://doi.org/10.1016/j.compedu.2022.104641

Daghriri, I., Liang, C. J., & Huang, W. (2024). Spatial immersive learning environments in primary education: A review of impacts and implementation challenges. *I-DO '24: Proceedings of the 2024 International Conference on Information Technology, Data Science, and Optimization,* (pp. 99–105). ACM. https://doi.org/10.1145/3658549.3658572

Dakeev, U., Pecen, R. R., Yildiz, F., & Luong, Y. (2021). Augmented reality computer-aided design education (ARCADE) tool to improve student motivation, engagement, and spatial cognition. *ASEE Annual Conference and Exposition*, (pp. 1-13). ASEE Peer. https://doi.org/10.18260/1-2--36730

Deliyiannis, I., Floros, A., Vlamos, P., Arvanitis, M., & Tania, T. (2008). Bringing digital multimedia in mathematics education. *Proc. Euro. Conf. e-Learn*, (pp. 290-296). ECEL. file:///D:/Bringing_Digital_Multimedia_in_Mathematics_Educati.pdf

Dewi, R. S. I., & Mudrikah, M. (2023). Analisis implementasi kurikulum merdeka pada sekolah penggerak di SDN 1 Selorejo Kecamatan Dau Kabupaten Malang. *Jurnal Simki Pedagogia*, *6*(2), 500–511. https://doi.org/10.29407/jsp.v6i2.327

Gargrish, S., Mantri, A., & Kaur, D. P. (2020). Augmented reality-based learning environment to enhance teaching-learning experience in geometry education. *Procedia Computer Science*, *172*, 1039–1046. https://doi.org/10.1016/j.procs.2020.05.152

Green, M., Challoo, L., & Mehrubeoglu, M. (2021). Finding a path forward for integrating augmented reality into K-12 classrooms: A literature review. In D. Russell (Ed.), *Advances in Educational Technologies and Instructional Design* (pp. 1–33). IGI Global. https://doi.org/10.4018/978-1-7998-4222-4.ch001

Herman, T., Arifin, S., Utami, N. S., & Fathiyah, I. (2023). Students' mathematics anxiety during distance learning: A survey on primary school students during COVID-19. *Journal of Engineering Science and Technology*, *18*, 239–252. https://jestec.taylors.edu.my/Special%20Issue%20ISCoE%202022_1/ISCoE%201_20.pdf

Herrera, L. M. M., Juárez Ordóñez, S., & Ruiz-Loza, S. (2024). Enhancing mathematical education with spatial visualization tools. *Frontiers in Education*, *9*, 1-13. https://doi.org/10.3389/feduc.2024.1229126

Javaheri, H., Lehmann, J., Altmeyer, K., Müller, L. M., Brünken, R., & Lukowicz, P. (2022). Design of augmented reality based environment to promote spatial imagination for mathematics education in elementary school. *Proceedings of the 2022 ACM International Joint*

Conference on Pervasive and Ubiquitous Computing, (pp. 274–277). ACM. https://doi.org/10.1145/3544793.3560380

Koumpouros, Y. (2024). Revealing the true potential and prospects of augmented reality in education. *Smart Learning Environments*, *11*(2), 1-62. https://doi.org/10.1186/s40561-023-00288-0

Krüger, J. M., Buchholz, A., & Bodemer, D. (2019). Augmented reality in education: Three unique characteristics from a user's perspective. *Proceedings of the 27 th International Conference on Computers in Education*, (pp. 412–422). APSCE Library. file:///D:/Manuscript.pdf

Lampropoulos, G., Keramopoulos, E., Diamantaras, K., & Evangelidis, G. (2022). Augmented reality and gamification in education: A systematic literature review of research, applications, and empirical studies. *Applied Sciences*, *12*(13), 1-43. https://doi.org/10.3390/app12136809

López-Faican, L., & Jaen, J. (2020). EmoFindAR: Evaluation of a mobile multiplayer augmented reality game for primary school children. *Computers & Education*, *149*, 103814. https://doi.org/10.1016/j.compedu.2020.103814

Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K–12 education: A review of the literature. *Technology, Pedagogy and Education*, *29*(2), 231–249. https://doi.org/10.1080/1475939X.2020.1737210

Mandala, A. S., Anwar, L., Sa'dijah, C., & Zulnaidi, H. (2025). Development of mobile augmented reality-based geometry learning games to facilitate spatial reasoning. *Infinity Journal*, *14*(2), 323–348. https://doi.org/10.22460/infinity.v14i2.p323-348

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7), 1-6. https://doi.org/10.1371/journal.pmed.1000097

Nadzeri, M. B., Musa, M., Cheng Meng, C., & Ismail, I. M. (2024). The effects of augmented reality geometry learning applications on spatial visualization ability for primary school pupils. *International Journal of Interactive Mobile Technologies (iJIM)*, *18*(16), 104–118. https://doi.org/10.3991/ijim.v18i16.47079

Ng, O.-L., Shi, L., & Ting, F. (2020). Exploring differences in primary students' geometry learning outcomes in two technology-enhanced environments: Dynamic geometry and 3D printing. *International Journal of STEM Education*, *7*(50), 1-13. https://doi.org/10.1186/s40594-020-00244-1

Olim, S. C., & Nisi, V. (2020). Augmented reality towards facilitating abstract concepts learning. In N. J. Nunes, L. Ma, M. Wang, N. Correia, & Z. Pan (Eds.), *Entertainment Computing – ICEC 2020* (Vol. 12523, pp. 188–204). Springer International Publishing. https://doi.org/10.1007/978-3-030-65736-9_17

Pellas, N., Kazanidis, I., & Palaigeorgiou, G. (2020). A systematic literature review of mixed reality environments in K-12 education. *Education and Information Technologies*, *25*(4), 2481–2520. https://doi.org/10.1007/s10639-019-10076-4

Perifanou, M., Economides, A. A., & Nikou, S. A. (2023). Teachers' views on integrating augmented reality in education: Needs, opportunities, challenges and recommendations. *Future Internet*, *15*(20), 1-18. https://doi.org/10.3390/fi15010020

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014). Collaborative augmented reality in education: A review. *Proc.- Int. Conf. Teach. Learn. Comput. Eng., LATICE*, (pp. 78–83). IEEE. https://doi.org/10.1109/LaTiCE.2014.23

Pradana, L. N., Sa'dijah, C., Sulandra, I. M., & Sholikhah, O. H. (2020). Virtual mathematics kits (VMK): The value of spatial orientation on it. *European Journal of Educational Research*, *9*(3), 1105–1114. https://doi.org/10.12973/eu-jer.9.3.1105

Putri, A., Wahyuningsih, T., Ananti, N. S., Wicaksono, A., Shofa, G. Z., As'ari, A. R., Purwanto, P., & OsmanP, S. (2023a). EUCLIDA: 3D augmented reality card for learning numeracy about geometry. *TEM Journal*, *12*(2), 1174–1181. https://doi.org/10.18421/TEM122-63

Radu, I., Doherty, E., DiQuollo, K., McCarthy, B., & Tiu, M. (2015). Cyberchase shape quest: Pushing geometry education boundaries with augmented reality. *Proc. IDC: Int. Conf. Interact. Des. Child.*, (pp. 430–433). ACM. https://doi.org/10.1145/2771839.2771871

Sa'dijah, C., Murtafiah, W., Anwar, L., & Sa'diyah, M. (2023). Exploring the content knowledge of prospective mathematics teacher students in designing HOTS Questions. *The 5th International Conference on Mathematics and Science Education (ICOMSE) 2021: Science and Mathematics Education Research: Current Challenges and Opportunities*, *2569*(1). https://doi.org/10.1063/5.0113669

Saif, A. F. M. S., Mahayuddin, Z. R., & Shapi'i, A. (2021). Augmented reality based adaptive and collaborative learning methods for improved primary education towards fourth industrial revolution (IR 4.0). *International Journal of Advanced Computer Science and Applications*, *12*(6), 614–623. https://doi.org/10.14569/IJACSA.2021.0120672

Salinas, P. (2017). Augmented reality: Opportunity for developing spatial visualization and learning calculus. In *Mob. Technol. And Augment. Real. In Open Educ.* (pp. 54–76). IGI Global. https://doi.org/10.4018/978-1-5225-2110-5.ch003

Sanfilippo, F., Blazauskas, T., Salvietti, G., Ramos, I., Vert, S., Radianti, J., Majchrzak, T., & Oliveira, D. (2022). A perspective review on integrating VR/AR with haptics into STEM education for multi-sensory learning. *Robotics*, *11*(41), 1-20. https://doi.org/10.3390/robotics11020041

Schmid, A., & Korenova, L. (2024). Enhancing geometry learning with geogebra: A Study. *Proceedings of the 23rd European Conference on e-Learning - ECEL 2024*, *23*(1), 487–496. European Conference on e-Learning. https://papers.academic-conferences.org/index.php/ecel/article/view/2893

Schwarz, B. B., Prusak, N., Swidan, O., Livny, A., Gal, K., & Segal, A. (2018). Orchestrating the emergence of conceptual learning: A case study in a geometry class. *International Journal of Computer-Supported Collaborative Learning*, *13*(2), 189–211. https://doi.org/10.1007/s11412-018-9276-z

Serrano-Ausejo, E., & Mårell-Olsson, E. (2024). Opportunities and challenges of using immersive technologies to support students' spatial ability and 21st-century skills in K-12 education. *Education and Information Technologies*, *29*(5), 5571–5597. https://doi.org/10.1007/s10639-023-11981-5

Sun, K. T., & Chen, M. H. (2020). Utilizing MAR for remedial teaching of compound-cube-surface area at elementary school in Taiwan. *International Journal of Information and Communication Technology Education*, *16*(2), 18–35. https://doi.org/10.4018/IJICTE.2020040102

Supli, A. A., & Yan, X. (2024). Exploring the effectiveness of augmented reality in enhancing spatial reasoning skills: A study on mental rotation, spatial orientation, and spatial visualization in primary school students. *Education and Information Technologies*, *29*(1), 351–374. https://doi.org/10.1007/s10639-023-12255-w

Tarng, W., Huang, J.-K., & Ou, K.-L. (2024). Improving elementary students' geometric understanding through augmented reality and its performance evaluation. *Systems*, *12*(493), 1-28, 493. https://doi.org/10.3390/systems12110493

Wang, L., Zhang, Q., & Sun, D. (2025). Exploring the impact of an augmented reality-integrated mathematics curriculum on students' spatial skills in elementary school. *International Journal of Science and Mathematics Education*, *23*(2), 387–414. https://doi.org/10.1007/s10763-024-10473-3

Widiasih, W., Zakirman, Z., & Ekawati, R. (2023). Development of Augmented Reality Media to Improve Student Understanding of Optical Eyes System Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 912–919. https://doi.org/10.29303/jppipa.v9i2.2858

Xu, W.-W., Su, C.-Y., Hu, Y., & Chen, C.-H. (2022). Exploring the effectiveness and moderators of augmented reality on science learning: A meta-analysis. *Journal of Science Education and Technology*, *31*(5), 621–637. https://doi.org/10.1007/s10956-022-09982-z

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (160-174)
Online: http://journal.uny.ac.id/index.php/jitp

Addressing visual fatigue for student engagement: Needs analysis and animation-based *muhadatsah* design in boarding schools

Muhammad Fatih Budiman Putra[1] *, Idrus Afandi Akbar[2], Octa Syakila Salsabila[3], Ba'iq Kurnia Buana[3], Qussiyatur Rohmania[4]
[1] Universitas Islam Negeri Maulana Malik Ibrahim, Indonesia.
[2] Universitas Islam Negeri Syarif Hidayatullah, Indonesia.
[3] Universitas Dr. H. Sumarno, Indonesia.
[4] Universitas Negeri Jember, Indonesia.
***** Corresponding Author. E-mail: 240104320011@student.uin-malang.ac.id

ARTICLE INFO

Article History
Received:
1 January 2026;
Revised:
25 June 2026;
Accepted:
26 June 2026;
Available online:
31 June 2026.

Keywords
Animated video;
Muhadatsah learning;
Visual fatigue

ABSTRACT

Visual fatigue in learning environments is commonly associated with monotonous, text-heavy printed materials that provide limited visual stimulation. This study aims to identify students' visual learning needs and develop a contextual, modeling-based animated video prototype as an instructional intervention. Employing a Research and Development (R&D) approach based on the ADDIE model, the study was limited to the Analysis and Design phases and involved 28 seventh-grade students and one Arabic language teacher at Al-Hamra Islamic Boarding School Junior High School. Data were collected through participant observation, in-depth interviews, and expert validation. The findings indicate that: (1) students demonstrated behavioral resistance toward conventional textbooks, evidenced by physical damage to approximately 70% of the books, largely due to their text-heavy design; (2) the proposed prototype features animated characters representing Islamic boarding school students (santri) and dormitory-based settings to enhance emotional relevance and contextual authenticity; and (3) expert validation produced high feasibility scores from the subject-matter expert (93.3%), media expert (91.4%), and language expert (91.7%), with an overall average of 92.1%, categorized as "Highly Feasible." The study concludes that the contextual animated video prototype has strong theoretical validity as a potential solution for mitigating students' visual fatigue before production. Future research should continue through the Development, Implementation, and Evaluation phases and experimentally examine its effectiveness in improving students' speaking proficiency.

How to cite:
Putra, M. F. B., et al., (2026). Addressing visual fatigue for student engagement: Needs analysis and animation-based *muhadatsah* design in boarding schools. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 160-174. https://doi.org/10.21831/jitp.v13i2.94481

INTRODUCTION

Mastery of speaking skills (maharah al-kalam) occupies a pivotal role in Arabic language education as a means of global communication in the twenty-first century. Effective oral communication requires the seamless integration of linguistic competence with non-verbal elements including intonation, facial expressions, and situational context—to construct meaningful interaction (Alam, 2025; Zulharby et al., 2019). In line with the demands of twenty-first-century 4C

competencies (Critical Thinking, Collaboration, Communication, and Creativity), contemporary foreign language instruction is expected to provide authentic communicative experiences that extend beyond static printed texts. Achieving this objective requires instructional stimuli capable of accurately modeling real-life communicative situations for learners (Amrullah et al., 2024; Sarip et al., 2024). Within this context, the Multimedia Learning approach provides a critical theoretical foundation. Its dual-coding principle suggests that information is processed more effectively when verbal and visual representations are presented simultaneously, thereby strengthening long-term memory retention (Roziqi, 2020; Zhu & Yang, 2023). Consequently, visual media such as animated conversation videos function as cognitive scaffolding that enables learners to visualize linguistic contexts more efficiently than conventional instructional methods. Their integration therefore represents not merely a technological innovation but an essential pedagogical necessity for developing communicative competence (Jamshidi & Zare, 2023; Jumadil & Haniah, 2022; Khadawardi, 2022; Kurnia et al., 2023).

Islamic boarding schools (pesantren) possess distinctive educational characteristics, particularly the restriction of students' access to personal digital devices. Under such circumstances, classrooms are expected to serve as a "visual oasis," the primary gateway through which students experience authentic representations of the outside world via technology-enhanced learning media (Minasari, 2025). Although the integration of educational technology into the pesantren curriculum has become an increasingly important global discourse for narrowing the digital literacy gap, its implementation frequently encounters obstacles related to limited infrastructure and teachers' pedagogical readiness.

Consequently, the responsibility of teachers to provide high-quality audiovisual learning experiences becomes even more critical than in conventional schools (Nurdin et al., 2025). However, empirical evidence reveals a substantial discrepancy between this educational imperative and current classroom practice. The principal challenge in Arabic language instruction within pesantren extends beyond the complexity of instructional content to the persistent reliance on conventional teaching approaches, where printed textbooks remain the sole instructional resource (Oktafatricia et al., 2022; Yasin & Fadhlullah, 2025). As a result, muhadatsah instruction, which should foster dynamic communicative interaction, is often reduced to repetitive text-based routines, creating a paradox in which the curriculum aspires to cultivate adaptive twenty-first-century competencies while classroom practices remain constrained by traditional, media-poor instruction (Sholahudin et al., 2025).

The central issue addressed in this study concerns the emergence of visual fatigue resulting from the poor instructional design of Arabic learning materials. Preliminary observations of the Arabic textbooks currently used revealed predominantly monochromatic layouts characterized by text-heavy page designs, which negatively affect readability and students' ability to retain information (Feng et al., 2022; Ismail & Yusof, 2022). Beyond increasing learners' cognitive load, the absence of stimulating visual elements suppresses the development of visual thinking skills that are essential for helping students at the concrete operational stage comprehend abstract foreign-language concepts. Over time, this condition contributes to perceptual fatigue, whereby learners' brains automatically disregard visually unappealing information before meaningful cognitive processing can occur (Alomoush et al., 2023; Cheng et al., 2018).

The most tangible manifestation of this instructional design failure appears in students' behavioral resistance toward learning materials. This phenomenon is reflected in the extensive physical deterioration of Arabic textbooks, including missing covers, torn pages, and acts of vandalism that occur far more frequently than in visually enriched textbooks. Such evidence indicates a diminished sense of ownership resulting from inadequate integration between textual and visual elements, ultimately preventing students from forming meaningful emotional connections with the learning materials (Jamshidi & Zare, 2023; Widyanti & Muta'ali, 2022). Furthermore, an overreliance on printed textbooks creates substantial epistemological barriers to teaching maharah al-kalam, as static textual media are inherently incapable of representing the suprasegmental features of spoken language, including intonation, stress, rhythm, and facial expressions that are indispensable for constructing authentic communicative meaning. Consequently, students tend to

reduce conversation practice to reading aloud or mechanically memorizing scripted dialogues without developing genuine pragmatic competence (Amrullah et al., 2024). This problem is further exacerbated by instructional materials that remain dominated by grammatical-structural approaches while failing to provide adequate visual scaffolding for authentic conversational simulation. Such limitations ultimately impede learners' fluency, speaking proficiency, and confidence in spontaneous oral communication due to insufficient exposure to authentic speech models (Al-jarf & Mingazova, 2020; Sarip et al., 2024).

Previous studies have examined the shortcomings of Arabic instructional materials from multiple perspectives. From a visual design standpoint, research has demonstrated that the integration of text and imagery in secondary-level Arabic textbooks remains inadequate, resulting in insufficient visual scaffolding for effective learning (Jamshidi & Zare, 2023). Likewise, visually impoverished textbook designs have been shown to significantly hinder the development of visual thinking skills necessary for understanding abstract concepts (Alomoush et al., 2023). Studies conducted in Islamic boarding school contexts further indicate that the primary challenge lies not only in instructional content but also in pedagogical stagnation and the limited diversity of learning media (Minasari, 2025; Yasin et al., 2025).

In response, recent research has increasingly focused on the development of animation-based instructional media. Animated applications such as Plotagon and two-dimensional animation have demonstrated considerable effectiveness in enhancing student engagement and oral communication skills (Amrullah et al., 2024; Kalbun & Yasak, 2024), while video-based instructional models incorporating twenty-first-century 6C competencies have also been proposed (Sarip et al., 2024). Nevertheless, the majority of these studies emphasize product efficacy or general skill enhancement after implementation, with relatively limited attention devoted specifically to the Analysis and Design phases as a means of addressing visual fatigue within technology-restricted Islamic boarding school environments. This research addresses that gap by developing a context-specific instructional media prototype explicitly designed to alleviate visual fatigue while supporting the unique muhadatsah learning needs of santri.

To address these challenges, this study proposes the development of an Animaker-based animated instructional video employing a contextual modeling approach for muhadatsah instruction. Animation technology was selected because of its ability to perform text-to-picture transformation, converting abstract conversational scripts into concrete visual representations that simultaneously facilitate learners' understanding of linguistic meaning and social context (Kalbun & Yasak, 2024; Karkar et al., 2017). Recognizing that many educational media development projects fail due to insufficient planning during the early stages, this study deliberately limits its scope to the Analysis and Design phases of the ADDIE model. This focused approach is intended to ensure the development of a pedagogically robust blueprint whose conceptual validity has been rigorously established before progressing to the technically demanding and resource-intensive production stage (Jumadil & Haniah, 2022).

Based on the issues outlined above, this study addresses three research questions: (1) What are the characteristics of students' visual learning needs and the manifestations of visual fatigue within Islamic boarding school classrooms? (2) What design characteristics should an animated instructional medium possess to align with the social and cultural context of santri? (3) To what extent is the proposed instructional media design theoretically valid according to expert evaluation? Accordingly, this study aims to diagnose the underlying visual challenges encountered in muhadatsah instruction and to develop a pedagogically validated instructional media design capable of preventing learning fatigue before entering the production stage. The resulting blueprint is expected to serve as a reference model for the development of adaptive learning media in Islamic boarding schools, demonstrating that restrictions on students' access to personal digital devices should not prevent classrooms from providing immersive, visually engaging, and high-quality learning experiences that ultimately foster students' speaking proficiency.

METHOD

This study employed a Research and Development (R&D) approach by adopting the ADDIE instructional design model (Analyze, Design, Develop, Implement, and Evaluate) conceptualized by Branch (Branch, 2009).

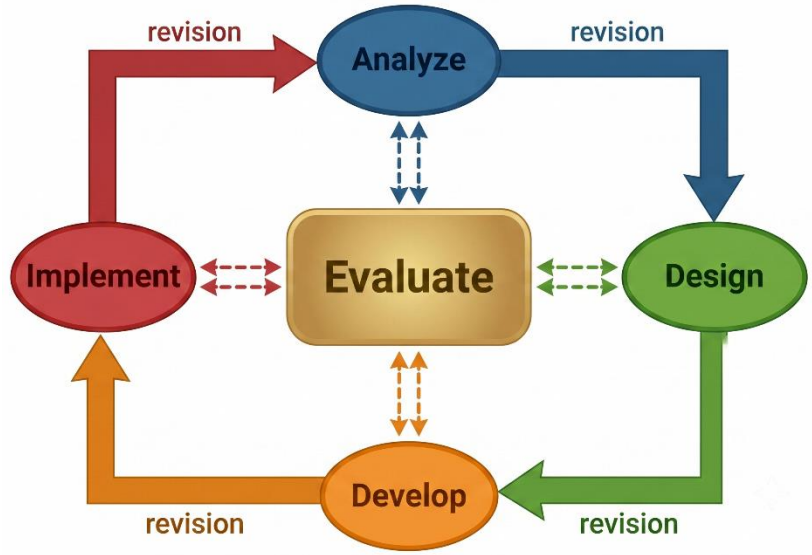

Figure 1. ADDIE Model

As illustrated in Figure 1, the ADDIE model consists of five cyclical and interconnected phases linked through a revision mechanism, allowing developers to revisit earlier stages whenever discrepancies are identified during the process of continuous evaluation. This iterative characteristic constitutes one of the primary reasons for selecting the ADDIE model, consistent with its application in instructional video development by Ulya et al., who demonstrated that systematic revision across development stages contributed substantially to the high validity of the final product (Ulya et al., 2021). The model was selected because of its systematic structure and its emphasis on addressing performance gaps through well-planned instructional design interventions. Although the generic ADDIE framework encompasses five sequential phases, the present study deliberately limited its scope to the first two foundational stages: (1) the Analysis phase and (2) the Design phase.

This methodological focus was based on the premise that the effectiveness of instructional media is largely determined by the accuracy of problem diagnosis and the robustness of the initial design concept. As emphasized by Jumadil & Haniah (2022), in their study on visual technology development, the failure of instructional media to enhance student engagement frequently stems from inadequate needs analysis and the absence of theoretically validated design prior to large-scale production. Furthermore, ensuring that the visual characteristics of instructional media are aligned with learners' religious and cultural values represents a critical consideration during the design process. This perspective is supported by Aeni et al., whose research on culturally responsive Islamic educational media highlighted the importance of contextualizing visual design for school-age learners (Aeni et al., 2022). Accordingly, the present study is positioned as design research, or more specifically, a preliminary study aimed at producing a pedagogically grounded blueprint and prototype of animated media for *muhadatsah* instruction. The proposed prototype was evaluated for both content validity and construct validity through expert judgment, thereby establishing a theoretically sound foundation for subsequent research encompassing the Development and Implementation phases of the ADDIE model.

The study was conducted at Al-Hamra Islamic Boarding School (IBS) Junior High School, a full-boarding educational institution operating within the Islamic boarding school (*pesantren*) system. This site was purposively selected because its institutional policy restricts students' access to personal digital devices. Such an environment provides an ideal ecological setting for investigating students' dependence on classroom instructional media as their primary source of visual stimulation,

as well as examining how limited variation in learning media contributes to visual fatigue during the learning process.

The participants were selected through purposive sampling and consisted of 28 seventh-grade students enrolled in a single classroom cohort. Seventh-grade students were intentionally chosen based on psychopedagogical considerations, as they are in a critical transitional stage from elementary education to the full-boarding school environment. At this stage, students are generally more susceptible to academic culture shock and learning boredom than their senior counterparts, making them an appropriate population for investigating visual fatigue in classroom learning. In addition to the student participants, one Arabic language teacher responsible for teaching *muhadatsah* served as the key informant to identify instructional challenges encountered during classroom practice. The study also involved three expert validators, comprising one expert in Arabic language instruction, one instructional media design expert, and one Arabic language expert. These experts were responsible for evaluating the theoretical feasibility and overall quality of the proposed instructional media prototype through expert judgment.

The development process was rigorously implemented by following the first two stages of the ADDIE model. The Analysis phase was designed to diagnose the existing performance gap through three complementary activities: performance analysis, needs analysis, and content analysis. Performance analysis focused on classroom observations of the teacher's instructional practices and the use of printed textbooks during *muhadatsah* instruction. Needs analysis explored students' visual preferences, learning experiences, and the manifestations of visual fatigue encountered throughout the instructional process. Content analysis examined the Grade VII *muhadatsah* curriculum to identify learning objectives, instructional content, and communicative competencies that should be represented in the proposed media.

The findings generated during the Analysis phase subsequently informed the Design phase, in which the identified instructional needs were translated into concrete product specifications. This phase involved the development of a comprehensive content map, the preparation of contextual dialogue scripts reflecting students' daily experiences in the Islamic boarding school environment, and the creation of character storyboards using the Animaker platform. The development procedure concluded with an expert judgment process to verify both the accuracy of the instructional content and the theoretical appropriateness of the media design before the prototype was finalized.

To ensure data triangulation, this study employed three complementary research instruments developed on the basis of visual fatigue indicators. Qualitative data were collected using an observation protocol and an in-depth interview guide. The observation protocol was designed to document the physical condition of students' Arabic textbooks, particularly signs of deterioration, as well as students' behavioral responses during classroom instruction. The in-depth interview guide was used to explore teachers' pedagogical challenges and students' psychological preferences regarding the use of animated instructional media. To evaluate the quality of the proposed prototype, quantitative data were obtained through expert validation sheets employing a five-point Likert scale. The validation instrument was specifically designed to assess two principal dimensions: content validity, evaluated by the Arabic language subject-matter expert, and construct validity, evaluated by the instructional media expert, with particular emphasis on visual aesthetics, readability, and instructional design quality.

The data were analyzed using complementary qualitative and quantitative techniques according to the nature of the data collected. Qualitative data obtained from classroom observations and in-depth interviews were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña, which consists of three iterative processes: data condensation, data display, and conclusion drawing and verification (Miles et al., 2015). During the data condensation stage, the analysis focused on identifying specific patterns associated with visual fatigue and students' instructional needs. The resulting diagnostic findings were then systematically organized to formulate the design specifications for the proposed instructional media.

Quantitative data derived from the expert validation process were analyzed using descriptive percentage statistics to determine the levels of content validity and construct validity of the proposed media design. The feasibility level of the instructional media prototype was calculated using the following formula:

$$P = \frac{\Sigma x}{\Sigma xi} \times 100\%$$

Information:
P = Feasibility Percentage
Σx = Total Score Awarded by the Validators
Σxi = Maximum Ideal Score

The resulting percentage scores were subsequently interpreted according to the feasibility criteria presented in Table 1.

Table 1. Interpretation Criteria for Prototype Feasibility

No.	Percentage Interval	Feasibility Category	Recommended Action
1	86%–100%	Highly Feasible	No Revision Required
2	76%–85%	Feasible	Minor Revision
3	66%–75%	Moderately Feasible	Revision Required
4	56%–65%	Less Feasible	Major Revision
5	<56%	Not Feasible	Complete Redesign Required

RESULTS AND DISCUSSION

Results

Based on observations conducted with 28 seventh-grade students, physical evidence regarding the condition of the printed instructional materials was documented. Field observations revealed that the majority of students' Arabic textbooks had undergone substantial physical deterioration. As illustrated in Figure 2, the damage included missing or severely damaged front covers, torn pages, and handwritten markings throughout the text. These findings provide tangible evidence of students' behavioral resistance toward the existing instructional materials, which had previously been identified during the needs analysis.

Figure 2. Physical Condition of Student Books

The observational findings were further corroborated by in-depth interviews conducted with student representatives and the Arabic language teacher. A summary of participants' perceptions regarding the instructional media currently used in *muhadatsah* classes is presented in Table 2.

Table 2. Summary of Interview Findings

No.	Participant	Key Response
1	Student (S-01)	"The textbook looks worn out because I rarely open it. It mostly contains text with very few illustrations. Reading it for a long time makes me feel sleepy and unmotivated. It would be much more interesting if it included more pictures."
2	Student (S-02)	"Honestly, I don't really like reading this book. It's printed in black and white, and the pages are filled with text, so it becomes tiring to look at."
3	Teacher (G-01)	"It is quite difficult to demonstrate conversational contexts using text alone because seventh-grade students still rely heavily on visual and audio support to understand communicative situations."

In addition, a comparative analysis of the existing instructional media identified a clear mismatch between the characteristics of the current textbooks and students' visual learning preferences. The existing textbooks are predominantly text-heavy, with more than 90% of the page content consisting of text presented in a monochromatic format. In contrast, students expressed a preference for instructional media incorporating diverse, dynamic, and visually engaging representations capable of supporting contextual understanding. Full Text Book, Black and White, and Minimal Visuals.

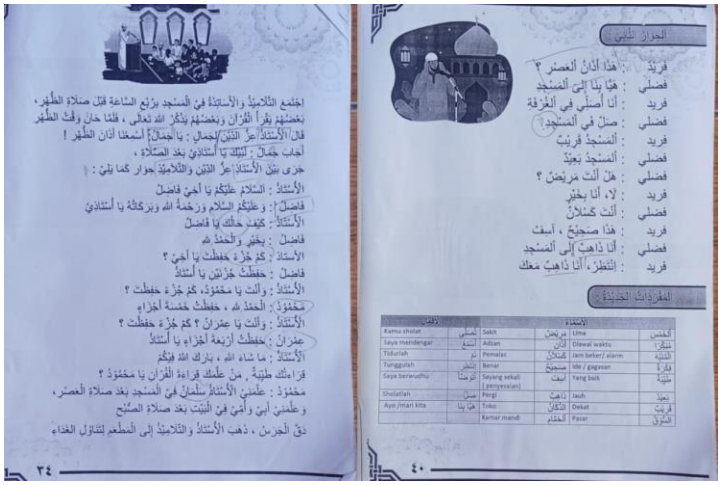

Figure 3. Full Text Book, Black and White, and Minimal Visuals

Based on the needs analysis, an animated instructional video prototype was designed using the Animaker platform. The prototype focused on *muhadatsah* materials covering Chapters 6 to 10 from the textbook *Fi Rihab Al-Hamra*. The instructional content and corresponding visual design specifications are presented in Table 3.

Table 3. Instructional Content Map and Visual Character Design

No.	Chapter	Conversation Topic	Setting	Main Characters
1	6	*Fi al-Masjid* (At the Mosque)	School Mosque Interior	Umar, Yusuf, Karim
2	7	*As-Shalah* (Prayer)	Congregational Prayer Area	Akbar, Abid
3	8	*Fi al-Mal'ab* (at the Sports Field)	Boarding School Basketball Court	Faqih, Ghani
4	9	*At-Tha'am* (Food)	School Cafeteria / Boarding School Courtyard	Wafi, Thoriq
5	10	*Fi al-Maktabah* (At the Library)	Library Bookshelves	Ilyas, Khalid

The animated characters were developed as custom-designed avatars to reflect the visual identity of *santri* in the Islamic boarding school environment. Characters such as Umar and Yusuf were specifically illustrated wearing traditional Muslim caps (*peci*) and robes that resemble the official student attire of the institution, distinguishing them from the default character templates provided by the Animaker platform. This contextualized visual design was intended to strengthen

learners' emotional engagement and to enhance the authenticity of the instructional experience through contextual modeling.

Figure 4. Character Design

The instructional sequence of the animated video was organized through a storyboard integrating conversational texts, native-quality neural voice narration, and character animation. An example of the storyboard developed for Chapter 6 (*Fi al-Masjid*) is presented in Table 4.

Table 4. Sample Storyboard of the Animated Instructional Video

No.	Scene	Visual Representation	Audio / Dialogue	Pedagogical and Design Rationale
1	01	Opening Scene. The video cover displays the chapter title and introduces the main characters. The title *"Chapter 6: Fi al-Masjid (At the Mosque)"* appears using a fade-in animation.	Background Music: Upbeat instrumental music. Narration: *"Al-Fashlu as-Sadis: Fi al-Masjid"* (Chapter Six: At the Mosque).	Attention Gaining: The introductory music and animated title are intended to capture students' attention and prepare them cognitively before the instructional content begins (pre-instructional strategy).
2	02	Greeting Scene (Tahiyyah). Umar approaches Yusuf and Karim, who are engaged in conversation. Umar raises his right hand to greet them.	Umar: *Assalamu'alaikum, O Yusuf and Karim.* Yusuf & Karim: *Wa'alaikumussalam.*	Social Modeling: The animation demonstrates appropriate etiquette when entering the mosque and greeting others. Hand gestures are synchronized with the dialogue to model culturally appropriate non-verbal communication practiced within the *santri* community.
3	03	Main Dialogue 1 (Reading Activity). The camera zooms in on Yusuf, who is holding an open copy of the Qur'an. Umar appears curious and asks a question.	Umar: *"What are you doing in the mosque, Yusuf?"* Yusuf: *"I am reading the Qur'an."*	Contextual Clues: The Qur'an serves as a visual cue enabling students to infer the meaning of the verb *aqra'u* ("to read") without relying on translation into Indonesian.
4	04	Main Dialogue 2 (Memorization Activity). The camera pans toward Karim, who briefly closes his eyes while placing his hand on his chest to indicate memorization and reflection.	Umar: *"And what are you doing, Karim?"* Karim: *"I am reviewing my Qur'an memorization."*	Differentiated Representation: Distinct visual actions differentiate *reading* (looking at the Qur'an) from *muraja'ah* (reviewing memorization), helping students understand the semantic differences between the two verbs through contextual visualization.

No.	Scene	Visual Representation	Audio / Dialogue	Pedagogical and Design Rationale
5	05	Closing Scene (Prayer and Appreciation). All three characters appear together. Umar raises both hands in prayer while Yusuf and Karim smile.	Umar: *"Masha Allah... May Allah make your memorization easier."* Karim: *"Allahumma Ameen."*	Affective Learning: The closing scene reinforces character education by encouraging students to appreciate and pray for one another's success, reflecting the values cultivated within the Islamic boarding school environment.

The proposed instructional media prototype subsequently underwent expert validation involving three specialists: an instructional media expert, an Arabic language instruction expert, and an Arabic language expert. All validation instruments employed a five-point Likert scale. A summary of the quantitative validation results is presented below.

Table 5. Validation Results from the Instructional Media Expert

No.	Evaluation Aspect	Items	Score	Percentage (%)	Category
1	Visual Design	6	26	86.7	Valid
2	Animation and Transitions	6	27	90.0	Highly Valid
3	Audio Quality	4	19	95.0	Highly Valid
4	Content Presentation	5	23	92.0	Highly Valid
5	Interactivity	3	14	93.3	Highly Valid
6	Compatibility	4	19	95.0	Highly Valid
Total / Average		**28**	**128**	**91.4**	**Highly Valid (Minor Revision)**

As shown in Table 5, the instructional media prototype obtained a total score of 128 out of a maximum possible score of 140, corresponding to a validity percentage of 91.4%. This result places the prototype within the Highly Valid category, indicating that it is appropriate for implementation following only minor revisions, primarily concerning aspects of visual design.

Table 6. Validation Results from the Arabic Language Instruction Expert

No.	Evaluation Aspect	Items	Score	Percentage (%)	Category
1	Instructional Content	10	47	94.0	Highly Valid
2	Language Structure	5	23	92.0	Highly Valid
Total / Average		**15**	**70**	**93.3**	**Highly Valid**

As presented in Table 6, the subject-matter expert assigned a score of 70 out of a maximum of 75, yielding a validity percentage of 93.3%. These findings indicate that the instructional content is well aligned with the competencies of *maharah al-kalam* and the developmental characteristics of the target learners. Accordingly, the prototype was judged to be highly valid and suitable for implementation without requiring substantial revisions.

Table 7. Validation Results from the Arabic Language Expert

No.	Evaluation Aspect	Items	Score	Percentage (%)	Category
1	Grammar	6	27	90.0	Highly Valid
2	Sentence Construction	3	14	93.3	Highly Valid
3	Vocabulary	3	14	93.3	Highly Valid
Total / Average		**12**	**55**	**91.7**	**Highly Valid (Minor Revision)**

The Arabic language expert awarded a total score of 55 out of a maximum possible score of 60, resulting in a validity percentage of 91.7%. This evaluation confirms that the Arabic language used throughout the instructional media generally conforms to accepted linguistic standards. Nevertheless, the expert recommended several minor revisions to improve wording, sentence formulation, and the accuracy of selected terminology.

Overall, the prototype achieved an average validity score of 92.1% across all three expert evaluations. According to the established feasibility criteria, this score places the instructional media within the Highly Feasible category. In addition to the quantitative evaluation, the instructional media

expert provided several qualitative recommendations, including improving the readability of Arabic subtitles, enhancing the consistency of background illustrations, and refining the color scheme used in the practice segments. These recommendations were incorporated into the revised version of the prototype before the final design was approved. The resulting revisions to the animated instructional media are presented in Table 8.

Table 8. Product Revision Process

No.	Before Revision	After Revision
1		
2		
3		

Discussion

The empirical finding that approximately 70% of the Arabic textbooks used at Al-Hamra Islamic Boarding School Junior High School exhibited severe physical deterioration should not be regarded as a routine occurrence. Rather, it represents a manifestation of students' behavioral resistance toward instructional materials that fail to accommodate their cognitive and visual learning needs. Students' reports of feeling "sleepy" and "tired" while reading monochromatic textbooks provide compelling evidence of visual fatigue during classroom learning. From the perspective of Cognitive Load Theory, this phenomenon can be explained by the excessive extraneous cognitive load imposed by text-heavy instructional materials (Sweller & Sciences, 2011). Students are required to devote substantial cognitive resources to decoding dense textual information without adequate visual support, thereby exhausting their working memory before meaningful comprehension can occur. This interpretation is consistent with Cheng et al., who demonstrated that instructional materials characterized by high textual density and low visual contrast significantly reduce students' sustained attention during learning (Cheng et al., 2018). Furthermore, these findings reinforce the argument proposed by Yusof et al. that rigid and visually unappealing Arabic textbooks are negatively associated with students' intrinsic motivation, ultimately contributing to apathetic

attitudes toward both learning and the physical maintenance of instructional materials (Yusof et al., 2024).

The instructional solution proposed in this study, namely the integration of animated characters representing *santri* through distinctive attributes such as the *peci* (traditional Muslim cap) and *baju koko* (Muslim shirt), together with authentic boarding school settings, constitutes a strategic application of contextual modeling (Lewicka & Waszau, 2017). This contextualized visual design directly addresses students' need for culturally relevant learning experiences by bridging their dual identities as school students and *santri* living in a boarding school environment. As argued by Kuraedah et al. and Suib and Baharudin, foreign language instruction becomes substantially more effective when instructional media reflect learners' social and cultural identities, thereby reducing the psychological distance between learners and the target language (Kuraedah et al., 2022; Suib & Baharudin, 2025). Moreover, the transition from static printed texts to animated instructional videos provides empirical support for Mayer's Multimedia Learning Theory, particularly the coherence and modality principles (Mayer, 2021). Previous research has similarly demonstrated that animation enhances multimedia learning by enabling learners to understand procedural and narrative content through dynamic visual representations (Kurniawan et al., 2019). By simultaneously presenting *muhadatsah* materials through visual channels (animated characters) and verbal channels (native-quality audio narration), the proposed instructional media provide concrete cognitive scaffolding that facilitates learners' understanding of pragmatic aspects of spoken Arabic, including intonation, facial expressions, and communicative gestures that cannot be adequately represented through printed text alone. Furthermore, the deliberate visual differentiation between conversational scenes clarifies semantic distinctions between verbs that are often ambiguous when taught using conventional translation-based approaches (Sarip et al., 2024).

The prototype achieved validity scores of 91.4% from the instructional media expert, 93.3% from the Arabic language instruction expert, and 91.7% from the Arabic language expert, indicating that the proposed instructional media satisfy rigorous standards of theoretical feasibility. These consistently high ratings demonstrate that limiting the scope of this study to the Analysis and Design phases of the ADDIE model should not be interpreted as a methodological limitation but rather as a deliberate preventive strategy to ensure the conceptual quality of the instructional product. As emphasized by Branch (2009), the design phase constitutes the core of instructional development, and the failure of educational products is more frequently attributable to inadequate instructional design than to technological limitations. Consequently, the "Highly Feasible" classification obtained in this study serves as an important quality assurance indicator, confirming that the pedagogical content remained conceptually accurate throughout its transformation into a digital instructional format. These findings further support the conclusions of (Jumadil & Haniah, 2022), who argued that investing substantial effort in systematic instructional design and expert validation significantly reduces the likelihood of major revisions during subsequent production stages, thereby increasing the readiness of instructional media for empirical implementation and large-scale effectiveness testing.

A major contribution of the present study lies in providing a practical instructional design model for Islamic boarding schools, which frequently face the challenge of balancing the preservation of educational traditions with the integration of contemporary technology. The findings introduce the concept of a "Visual Oasis," whereby animated instructional media function as a pedagogical window through which students can experience authentic simulations of real-world communication without violating institutional policies that restrict the use of personal digital devices. From a pedagogical perspective, the proposed instructional media transform *muhadatsah* instruction from a predominantly teacher- and text-centered approach into an immersive multimedia learning experience. By incorporating authentic representations of boarding school life, the media extend beyond their role as instruments for knowledge transmission and serve as psychological interventions that restore students' learning motivation diminished by visual fatigue. The contextualized prototype therefore demonstrates that limited access to digital devices and internet connectivity within Islamic boarding schools should not be viewed as barriers to modern Arabic language instruction, but rather as instructional design challenges that can be addressed through culturally responsive and contextually grounded media development.

Despite the high level of theoretical validity achieved by the proposed instructional media, several methodological limitations should be acknowledged and considered as directions for future research. The principal limitation concerns the scope of the development process, which was intentionally confined to the Analysis and Design phases of the ADDIE model. Consequently, the present study establishes only the theoretical feasibility of the prototype based on expert judgment and does not provide empirical evidence regarding its effectiveness in improving students' learning outcomes. As a result, the conclusions drawn from this research remain limited to demonstrating the prototype's potential for mitigating visual fatigue and its pedagogical appropriateness, rather than verifying measurable improvements in students' speaking proficiency. Future research is therefore encouraged to extend the prototype through the Development, Implementation, and Evaluation phases of the ADDIE model. Subsequent studies should employ experimental research designs involving control and experimental groups to examine the effectiveness of the contextualized animated instructional media in enhancing students' fluency and accuracy in *muhadatsah*. Furthermore, future investigations are encouraged to expand the instructional content to include more advanced conversational topics, thereby providing broader evidence of the effectiveness and scalability of the proposed instructional media across diverse Arabic language learning contexts.

CONCLUSION

Based on the findings of the analysis and design phases, this study draws three principal conclusions. First, the presence of visual fatigue among students at Al-Hamra Islamic Boarding School Junior High School was empirically confirmed through the extensive physical deterioration of students' Arabic textbooks, affecting approximately 70% of the materials, together with students' verbal reports describing the instructional materials as monotonous and lacking sufficient visual illustrations. Second, in response to these findings, the study successfully developed a prototype specification for animated instructional media for *muhadatsah* based on a Contextual Modeling approach using the Animaker platform. The novelty of the proposed design lies in its integration of *santri*-oriented character representations and authentic boarding school settings that closely reflect learners' sociocultural environment. Third, the proposed prototype demonstrated a high level of theoretical validity, achieving an average expert judgment score of 92.1%, which places it in the Highly Feasible category with respect to both instructional content and media design. From a theoretical perspective, these findings reinforce the view that, within technology-restricted boarding school environments, visual instructional media should not be regarded merely as supplementary learning resources but as essential psychological supports for sustaining student engagement and reducing visual fatigue. From a practical perspective, future instructional media developers are encouraged to extend this prototype through the Development and Implementation phases of the ADDIE model to examine its empirical effectiveness in improving students' learning outcomes. Furthermore, Arabic language teachers are encouraged to move beyond an exclusive reliance on printed textbooks and adopt contextually designed visual instructional media capable of modeling the non-verbal dimensions of spoken communication, including intonation, facial expressions, gestures, and authentic conversational contexts, thereby supporting the development of students' speaking proficiency.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Al-Hamra Islamic Boarding School Junior High School for granting permission and providing invaluable support throughout the research process. Special appreciation is extended to the Arabic language teacher and all seventh-grade students who generously participated in this study and contributed meaningful insights during the needs analysis stage. The authors also wish to thank the expert validators for their constructive feedback and professional evaluations, which substantially improved the quality and theoretical validity of the instructional media prototype. Finally, the authors are deeply grateful to all colleagues

and mentors whose continuous encouragement and support made the completion of this research possible.

REFERENCES

Aeni, A. N., Erlina, T., Dewi, D. P., & Hadi, F. L. (2022). Aplikasi BETA (belajar dari peta): Media edukasi doa-doa harian siswa SD kelas rendah. *Jurnal Inovasi Teknologi Pendidikan*, *9*(1), 101–113. https://doi.org/10.21831/jitp.v9i1.49203

Al-jarf, R. S., & Mingazova, N. G. (2020). Evaluation of Arabic Language teaching textbooks used in Russia in the light of the CEFR criteria. *Arpha IFTE*, *3*, 101–129. https://doi.org/10.3897/ap.2.e0101

Alam, S. (2025). Effects of multimedia inputs on improving the grammatical accuracy of students ' speaking skills: An experimental study. *Theory and Practice in Language Studies*, *15*(5), 1579–1590. https://doi.org/10.17507/tpls.1505.23

Alomoush, R. A., Hamadneh, M. A., Alissa, R. A. S., & Fraihat, N. B. F. (2023). An evaluation of ' our Arabic Language' book for the third grade according to visual thinking skills: Analytical study. *International Journal of Membrane Science and Technology*, *10*(3), 1940–1950. https://doi.org/10.15379/ijmst.v10i3.1863

Amrullah, M. K., Riwanda, A., & Wilailak, W. (2024). Elevating Arabic speaking skills: Plotagon and digital comics as catalysts for enhanced learning engagement and proficiency. *Al-Ta'rib Jurnal Ilmiah Program Studi Pendidikan Bahasa Arab*, *12*(1), 17–32. https://doi.org/10.23971/altarib.v12i1.7564

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.

Cheng, P., Su, Y., Chien, Y., Wu, T., & Huang, Y. (2018). An investigation of visual fatigue in elementary school students resulting from reading e-books. *Journal of Internet Technology*, *19*(5), 1285–1292. https://doi.org/10.3966/160792642018091905001

Feng, D., Lu, C., Cai, Q., & Lu, J. (2022). A study on the design of vision protection products based on children's visual fatigue under online learning scenarios. *Healthcare*, *10*(621), 1-11. https://doi.org/ 10.3390/healthcare10040621

Ismail, M., & Yusof, N. (2022). Textbook technical presentation vs. readability: An analysis of KBD form four Arabic textbooks in Malaysia. *Journal of Nusantara Studies*, *7*(2), 270–290. https://doi.org/10.24200/jonus.vol7iss2ppx270-290

Jamshidi, F., & Zare, S. (2023). An evaluation of junior high school grade two Arabic textbook pictures based on Slough and McTigue method. *Journal of Research in Arabic Language*, *15*(28), 63-84. https://doi.org/10.22108/RALL.2022.131018.1389

Jumadil, & Haniah. (2022). Visual technology development for Arabic learning based on ADDIE development model. *Al Maqayis: Jurnal Pendidikan Bahasa Arab dan Kebahasaaraban*, *9*(2), 147–160. https://doi.org/10.18592/jams.v9i2.5692

Kalbun, N. A., & Yasak, Z. (2024). The development of 2D animation video application for Arabic daily conversations. *Research and Innovation in Technical and Vocational Education and Training*, *4*(1), 109–117. https://doi.org/10.30880/ritvet.2024.04.01.013

Karkar, A. G., Mohamad, J., Am, A., & Mahmood, A. (2017). Illustrate it! An Arabic multimedia text-to-picture m-learning system. *IEEE Access*, *5*, 12777–12787. https://doi.org/10.1109/ACCESS.2017.2710315

Khadawardi, H. A. (2022). Teaching L2 Vocabulary Through Animated Movie Clips with English Subtitles. *International Journal of Applied Linguistics & English Literature*, *11*(2), 18–27. https://doi.org/10.7575/aiac.ijalel.v.11n.2p.18

Kuraedah, S., Gunawan, F., Alam, S., & Ubaidillah, M. F. (2022). Cultural representation in English and Arabic textbooks endorsed by Indonesian government: What do textbooks tell us about? *JSSER: Journal of Social Studies Education Research*, *13*(3), 229–255. https://jsser.org/index.php/jsser/article/view/4402

Kurnia, F. A., Aprilia, R., & Muhammad, H. (2023). Utilization of interactive learning media based on the Plotagon application in learning Arabic speaking skills. *AKADEMIKA: Jurnal Teknologi Pendidikan*, *12*(02), 365–380. https://doi.org/10.34005/akademika.v12i02.3326

Kurniawan, F. Y., Siahaan, S. M., & Hartono, H. (2019). Pengembangan multimedia interaktif berbasis aventure game pada materi prinsip animasi. *Jurnal Inovasi Teknologi Pendidikan*, *6*(2), 183–195. https://doi.org/10.21831/jitp.v6i2.27259

Lewicka, M., & Waszau, A. (2017). Analysis of textbooks for teaching Arabic as a foreign language in terms of the cultural curriculum. *Universal Journal of Educational Research*, *5*(1), 36–44. https://doi.org/10.13189/ujer.2017.050105

Mayer, R. (2021). *Multimedia learning*. Cambridge University Press. https://doi.org/10.1017/9781316941355

Miles, M., Huberman, A. M., & Saldana, J. (2015). *Qualitative data analysis a methods sourcebook*. SAGE Publication.

Minasari, A. (2025). Utilization of digital media among students at international islamic boarding schools. *Qalamuna: Jurnal Pendidikan Sosial dan Agama*, *17*(1), 421–432. https://doi.org/10.37680/qalamuna.v17i1.5866

Nurdin, A., Anwar, S., & In'am, A. (2025). Integration of technology in Islamic boarding schools curriculum in Indonesia: A systematic literature review on integrative curriculum models and innovations in learning. *International Journal of Social Science & Interdisciplinary Research*, *14*(09), 29–40. https://www.gejournal.net/index.php/IJSSIR/article/view/2732

Oktafatricia, E., Aslamiyah, S., & Syahrir, S. (2022). A study of Arabic textbooks for madrasah tsanawiyah. *Al-Bayan: Jurnal Jurusan Pendidikan Bahasa Arab*, *14*(2), 421–437. https://doi.org/10.24042/albayan.v14i2.9671

Roziqi, M. A. (2020). Development of pictorial textbook for Arabic speaking skill in Islamic studies program. *Izdihar : Journal of Arabic Language Teaching, Linguistics, and Literature*, *2*(3), 217–230. https://doi.org/10.22219/jiz.v2i3.10161

Sarip, M., Ilham, A., & Bahtiar, I. R. (2024). Integrated 6C skills of the 21st century with animation video media for Arabic speaking material design. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran*, *10*(1), 183–194. https://doi.org/10.33394/jk.v10i1.10549

Sholahudin, S., Munawar, A., & Abdurrahman, M. (2025). Analysis of Arabic textbook for grade VII merdeka curriculum based on textbook praxeological analysis. *Didaktika: Jurnal Kependidikan*, *14*(1), 1159–1168. https://doi.org/10.58230/27454312.1865

Suib, N. S. M., & Baharudin, H. (2025). Effective strategies for teaching Arabic prosody in oral communication skills. *Qubahan Academic Journal*, *5*(1), 169–180. https://doi.org/10.48161/qaj.v5n1a855

Sweller, J., & Sciences, L. (2011). The split-attention effect. In *Cognitive Load Theory* (pp. 111-128). Springer. https://doi.org/10.1007/978-1-4419-8126-4

Ulya, F. I., Sumarno, & Wijayanti, A. (2021). Pengembangan media video berbasis discovery learning untuk siswa sekolah dasar. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 68–83. https://doi.org/10.21831/jitp.v8i1.42565

Widyanti, A. R., & Muta'ali, A. (2022). The Suitability of visual images in Baina Yadaik Arabic textbook. *Arabiyat: Jurnal Pendidikan Bahasa Arab dan Kebahasaaraban*, *9*(2), 137–150. https://doi.org/10.15408/a.v9i2.28987

Yasin, A., & Fadhlullah, M. (2025). The problematics of Arabic Language learning at Islamic boarding school. *Arabic Language, Literature, and Education* *6*(1), 1–15. https://doi.org/10.37680/aphorisme.v6i1.6442

Yasin, A., Rinawati, T. E. T., & Putri, N. R. (2025). Using Kahoot application as interactive media in the Arabic speaking skills development. *Arabiyat : Jurnal Pendidikan Bahasa Arab dan Kebahasaaraban*, *12*(01), 99–111. https://doi.org/10.15408/a.v12i1.41276

Yusof, M. A. M., Rahman, A. A., Ismail, N., & Ghani, M. T. A. (2024). The readiness of KAFA Arabic teachers towards utilizing augmented reality in teaching Arabic vocabularies. In *Artificial Intelligence (AI) and Customer Social Responsibility (CSR). Studies in Systems, Decision and Control* (Vol. 517, pp. 815–821). Springer. https://doi.org/10.1007/978-3-031-50939-1_65

Zhu, T., & Yang, Y. (2023). Research on mobile learning platform interface design based on college students' visual attention characteristics. *PLoS ONE*, *18*(07), 1–16. https://doi.org/10.1371/journal.pone.0283778

Zulharby, P., Rasyid, Y., & Nuruddin. (2019). The characteristics of teaching material Arabic speaking skills in higer education. *Jurnal Al Bayan: Jurnal Jurusan Pendidikan Bahasa Arab*, *11*(2), 194–213. https://doi.org/10.24042/albayan.v11i2.5175

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (175-183)
Online: http://journal.uny.ac.id/index.php/jitp

Gamified simulation to improve student comprehension and motivation in transportation systems

Abduh Sayid Albana*, Desita Nur Rachmaniar, Granita Hajar
Universitas Telkom, Indonesia.
* Corresponding Author. E-mail: abduhalbana@telkomuniversity.ac.id

ARTICLE INFO

Article History
Received:
9 October 2025;
Revised:
27 June 2026;
Accepted:
27 June 2023;
Available online:
30 June 2026.

Keywords
Gamification; Logistics simulation; Transportation system

ABSTRACT

This study investigates the effectiveness of a gamified transportation simulation game in improving student comprehension and motivation within a Logistics Engineering course. Employing a pre-experimental pre-test/post-test design, the study involved a sample of 24 undergraduate students. The study collected data using performance penalty scores to measure comprehension and adapted questionnaires to assess motivation. To address methodological rigors, the instrument's reliability was validated (Cronbach's Alpha = 0.881), and the data were analyzed using the robust non-parametric Wilcoxon Signed-Rank Test. The results indicate that the gamified intervention significantly enhanced both students' problem-solving accuracy and their intrinsic motivation to learn complex logistics concepts ($p < 0.001$). The study's primary contribution lies in its methodological novelty: a dynamic penalty scoring system based on the deviation between students' manual calculations and optimal algorithmic solutions, integrated within a scaffolded learning environment. Theoretically, this research reinforces constructivist learning by bridging abstract mathematical formulations with interactive gamification. Practically, it provides an easily deployable educational tool for engineering curricula. However, the study's limitations include a small sample size, the absence of a control group, and potential testing effects. Future implementations should address these gaps further to validate the tool's scalability and long-term impact.

How to cite:
Albana, A. S., Rachmaniar, D. N., & Hajar, G. (2026). Gamified simulation to improve student comprehension and motivation in transportation systems. *Jurnal Inovasi Teknologi Pendidikan, 13*(2), 175-183. https://doi.org/10.21831/jitp.v13i2.90346

INTRODUCTION

The ability to manage transportation and distribution systems is a mandatory competency for graduates of the Bachelor's Degree of Logistics Engineering program. This requirement is outlined in the 2024 curriculum guide. According to the curriculum, graduates must possess skills in managing transportation routes and scheduling, as well as understanding key elements related to transportation costs. Based on the exit survey from the bachelor's program, 60.9% of respondents rated the ability to design and improve logistics systems as important, while 39.1% rated it as very important. This emphasis is further supported by alumni feedback, which identified the Transportation Systems course as one of the most relevant in preparing them for professional roles.

However, the Transportation Systems course in the Logistics Engineering bachelor program at the Surabaya Campus is implemented significantly below the standard of similar programs at the

main campus. The Logistics Engineering bachelor program in Surabaya also has the lowest student enrollment among all study programs at Telkom University Surabaya Campus. Furthermore, the academic capabilities of incoming students are generally lower compared to those at the main campus. One of the main challenges hindering students' understanding of transportation and distribution systems is their difficulty in grasping the underlying mathematical formulations and algorithms used to solve transportation problems. Typically derived from real-world transportation and distribution scenarios, these formulations can be abstract and difficult to comprehend without sufficient context or visualization. Therefore, educational tools that bridge this gap are essential to support student learning.

While previous studies have utilized simulation-based approaches to teach transportation and distribution concepts, they often lack critical integration of mathematical validation. For instance, Abasian et al.,(2020) and D'Amours & Rönnqvist (2013) developed effective games for supply chain planning and collaborative logistics, respectively, but their focus remained largely on high-level strategic decision-making. Similarly, interactive tools by Gaudron et al., (2019), Fjeld & Hedlinger (2005), Klock et al., (2021), and Kourounioti et al., (2018) successfully visualized urban distribution and transport planning and synchro-modal decision-making, yet they functioned more as descriptive scenarios rather than rigorous algorithmic challenges. Meanwhile, recent developments in digital simulations for vocational and technical education have shown broader promise in enhancing conceptual engagement (Hakim et al., 2022; Rahman et al., 2026; Rahmat et al., 2019; Romero et al., 2017; Tiari et al., 2020). Recent computational research highlights the growing trend of gamifying complex operations research tasks, such as the Vehicle Routing Problem (Kullman et al., 2025). However, translating these advanced concepts into accessible, curriculum-based educational tools remains a challenge.

Furthermore, comprehensive reviews on gamification in education by Koivisto & Hamari (2019), Deterding et al., (2011), and Majuri et al., (2018) reveal a heavy reliance on basic achievements-oriented elements such as points and leaderboards without linking these rewards directly to algorithmic accuracy and mathematical comprehension. A critical research gap remains in combining progressive problem complexity with real-time algorithmic feedback to teach operations research formulations.

This study fills that gap by introducing a conceptual and methodological novelty beyond local implementation context. We developed a gamified simulation featuring a dynamic penalty scoring system based on the exact deviation between a student's manual calculation and the optimal algorithmic solution. This mechanism is combined with instructional scaffolding, gradually increasing problem complexity from the Traveling Salesman Problem (TSP) to the Vehicle Routing Problem with Time Window (VRP-TW). The expected contribution of this research is twofold: theoretically, it provides empirical evidence on how integrating competitive algorithmic feedback within a constructivist framework enhances cognitive retention in STEM education; practically, it offers a validated, interactive learning tool that can be adopted by other engineering programs facing similar challenges in teaching abstract logistics models.

This research concludes that the developed gamified transportation simulation successfully improves both student comprehension and learning motivation when dealing with complex operations research problems. By utilizing a scaffolded level architecture and a dynamic algorithmic penalty scoring mechanism, the educational tool directly answered the study's core objectives: it significantly minimized manual routing errors and drastically elevated students' analytical confidence. The primary practical contribution of this study is the delivery of a validated, lightweight, and easily deployable Microsoft Excel prototype tailored for engineering curricula facing enrollment and resource constraints. Future implementations will scale this tool across larger student cohorts and introduce a control group framework to further validate its long-term learning retention metrics.

METHOD

Research Design

This study employed a quantitative evaluation approach utilizing a pre-experimental, one-group pre-test/post-test design. The primary objective was to assess whether a gamified transportation simulation could enhance students' comprehension and engagement in transportation and distribution systems.

Population and Sample

This study employed a quantitative evaluation approach utilizing a pre-experimental, one-group pre-test/post-test design. The primary objective was to assess whether a gamified transportation simulation could enhance students' comprehension and engagement in transportation and distribution systems. The population comprised undergraduate students enrolled in the Transportation Systems course at the Surabaya campus. The sample consisted of 24 sophomore students (58% female, 42% male) divided into six collaborative groups. None of the participants had prior experience with transportation optimization software. The use of a concise three-week intervention period was deliberately chosen to minimize internal validity threats, such as maturation and history effects.

Instruments and Intervention

Data were gathered using two main instruments: the simulation game (measuring comprehension) and a questionnaire (measuring motivation).

Transportation Simulation Game (Intervention Tool)

The gamified approach progressively increased problem complexity across five classic operations research levels: (1) Traveling Salesman Problem (TSP), (2) Multi-TSP or Vehicle Routing Problem (VRP), (3) Capacitated Vehicle Routing Problem (CVRP), (4) Vehicle Routing with Pickups and deliveries (VRP-PD), and (5) Vehicle Routing with Time Windows (VRP-TW). The game prototype, developed in Microsoft Excel, utilizes a point-based penalty system. The appearance of the game prototype is shown in Figure 1 for the main menu and Figure 2 for the problem interface.

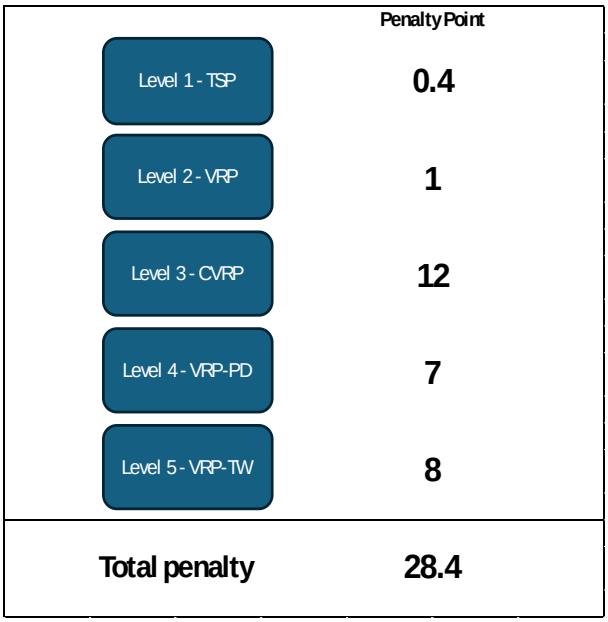

Figure 1. The Main Menu of Transportation Simulation Game

Each level features four primary functionalities: a Randomize Button (to generate coordinates within a 10x10 grid), a Lock Location Button, a Solve Button (activating the optimal algorithm), and a Result Input Field.

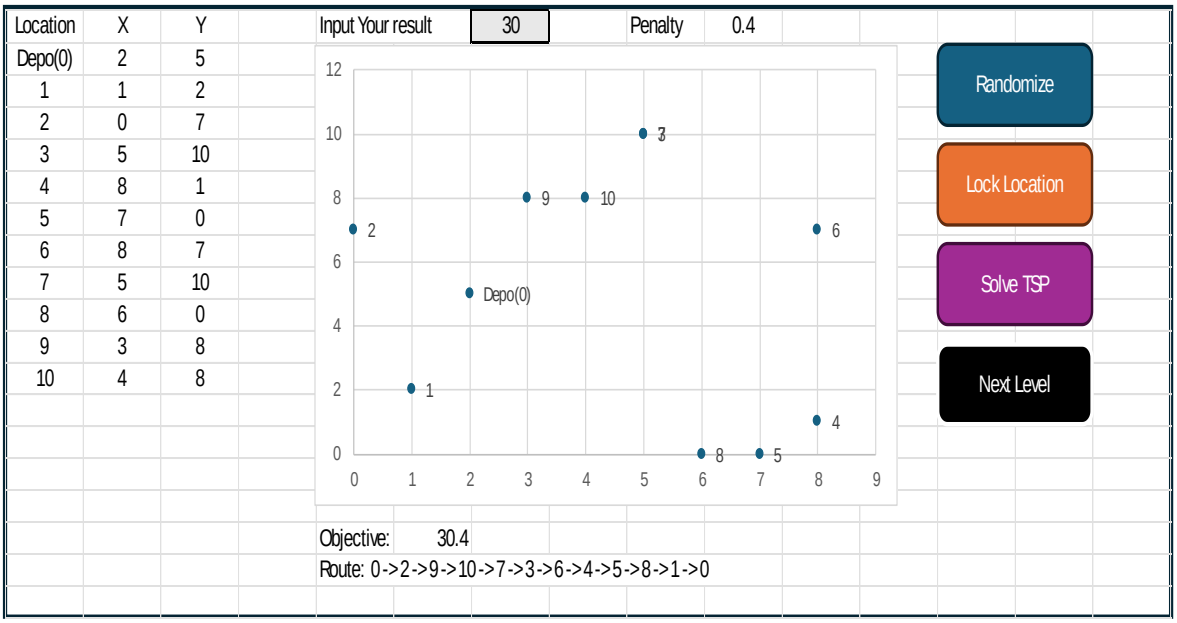

Figure 2. The Interface of Each Level of the Problem

Students are required to input their manually calculated solutions into the system before using the built-in algorithm. The system calculates a penalty score based on how far the manual solution deviates from the optimal algorithmic result. The lower the accumulated penalty points, the better the student's comprehension.

Motivation Questionnaire

Motivation and interest were assessed using a 4-point Likert scale questionnaire adapted from reliable tools in technical education (Daroini et al., 2022; Daroini & Alfiana, 2022), and supported by related instructional module studies (Buulolo, 2025; Sriyunianti et al., 2022; Tasya et al., 2023). To ensure the instrument's trustworthiness for this specific cohort, construct validity and internal consistency were thoroughly evaluated. The reliability test yielded a strong Cronbach's Alpha of 0.881 for the overall questionnaire. Furthermore, Pearson Product-Moment correlations confirmed that the majority of items had significant positive correlations with the total score ($p < 0.05$), establishing robust construct validity.

Data Collection Procedure

To ensure replicability, the data collection was systematically conducted in three distinct phases over three weeks:

1. Week 1 (Pre-test): Students completed the pre-questionnaire to gauge baseline motivation. They then played the simulation using their existing knowledge, and their initial penalty scores were recorded.
2. Week 2 (Intervention): Students received instructional treatment on the correct algorithms to solve the problems, such as the nearest neighbor logic for TSP and the clustering method for VRP.
3. Week 3 (Post-test): Students re-applied the simulation game to obtain their new penalty scores, followed by the post-questionnaire to identify any significant changes in motivation and understanding.

Data Analysis Techniques

The collected data were evaluated to determine significant differences before and after the intervention. To determine the appropriate statistical test, a Shapiro-Wilk normality test was executed first on both the pre-test and post-test scores. The analysis confirmed that the dataset significantly deviated from a normal distribution ($p < 0.05$), meaning the standard assumptions required for

parametric statistics were formally violated. Due to this violation, the small sample size (N=24), and the ordinal nature of the questionnaire data, a non-parametric Wilcoxon Signed-Rank Test was employed as the definitive, robust alternative to parametric paired *t*-test frameworks (Field, 2024; Hair et al., 2019). This step-by-step approach ensures that interpretations regarding cognitive gains and motivational increases are mathematically justified and not compromised by zero-variance or normality issues inherent in small datasets.

RESULTS AND DISCUSSION

Results

Prior to evaluating the intervention's impact, the reliability of the adapted questionnaire was tested. The results in Table 1 demonstrate that all questionnaire dimensions possess excellent internal consistency, well above the acceptable threshold of 0.70 established in educational research.

Table 1. Instrument Reliability Results

No.	Dimension / Variable	Number of Items	Cronbach's Alpha	Status
1	Motivation and Interest in Learning	7	0.720	Reliable
2	Understanding of the Material	8	0.737	Reliable
3	Application of Programs in Learning	8	0.804	Reliable
Overall Questionnaire		**23**	**0.881**	**Highly Reliable**

The primary analysis measured differences in both comprehension (Penalty Score) and motivation before and after the gamification intervention. Table 2 presents the descriptive statistics detailing the average scores for each questionnaire item before and after the intervention, illustrating a consistent upward trend in student responses across all indicators.

Table 2. Detailed Items and the Recapitulation Result of the Questionnaire

No.	Categories	Average Before	Average After
Motivation and Interest in Learning			
1	I like the Transportation Systems course.	2.00	3.00
2	I want to become proficient in route planning.	3.00	3.00
3	I enjoy being given real-life examples in the material and problems being studied.	3.00	3.00
4	I enjoy solving problems related to the field of transportation.	2.00	3.00
5	I do not give up easily when faced with difficult problems.	2.00	3.00
6	I actively participate in the learning process.	2.00	3.00
7	I consider this course important and beneficial for my future.	3.00	3.00
Understanding of the Material			
1	I can easily grasp the material being taught.	1.00	2.00
2	I am not afraid of making mistakes when solving problems during the learning process.	2.00	3.00
3	I like being given many opportunities to ask questions about material I do not understand.	2.00	3.00
4	I understand more easily when the lecturer introduces various ways to solve a problem.	2.00	3.00
5	I understand the material more easily when using a problem-solving program.	2.00	3.00
6	I can apply the concepts I've learned in various situations or problems.	2.00	3.00
7	I can identify the correct steps to solve problems.	1.00	2.00
8	I need media, tools, and learning facilities to improve my understanding of the material.	2.00	3.00
Application of Programs in Learning			
1	I use programs to solve problems that are difficult to handle manually.	2.00	3.00

No.	Categories	Average Before	Average After
2	I understand problems more easily using transportation simulation programs.	2.00	3.00
3	My understanding improves when I use the program.	2.00	2.00
4	I feel more motivated to learn when I use a program to solve problems.	2.00	3.00
5	Using the program supports me in thinking logically.	2.00	3.00
6	The program is very helpful for me in solving problems.	2.00	3.00
7	Using the program improves my problem-solving ability.	2.00	3.00
8	The program helps me analyze problems.	2.00	3.00

To determine the statistical significance of these improvements, a Wilcoxon Signed-Rank Test was conducted. Table 3 presents the consolidated inferential results. The analysis reveals a statistically significant improvement in students' conceptual comprehension, evidenced by a dramatic reduction in mean penalty scores from 17.88 to 10.53 ($p < 0.001$). Similarly, the overall motivation questionnaire scores demonstrated a highly significant increase across all assessed dimensions.

Table 3. Wilcoxon Signed-Rank Test Results

No.	Tested Category	Mean Before	Mean After	Wilcoxon Stat (W)	P-Value	Statistical Significance
1	Penalty Score (Comprehension Metric)	17.88	10.53	0.0	< 0.001	Highly Significant (Error reduction)
2	Category 1: Motivation & Interest	16.17	23.04	0.0	< 0.001	Highly Significant (Increase)
3	Category 2: Material Understanding	17.08	25.08	0.0	< 0.001	Highly Significant (Increase)
4	Category 3: Program Application	17.08	25.04	0.0	< 0.001	Highly Significant (Increase)

Discussion

The findings robustly support the hypothesis that integrating a gamified simulation significantly enhances both student comprehension and learning motivation in transportation systems. Rather than relying on the rote memorization of formulas, students who engaged with the simulation exhibited a deeper cognitive grasp of the material.

A critical factor contributing to this outcome is the system's architecture, specifically the dynamic penalty scoring mechanism. By immediately calculating and displaying the deviation between the students' manual calculations and the optimal algorithmic solutions, the game provides real-time, objective feedback. This forces students to actively iterate and critically evaluate their routing decisions, mimicking the mechanics of metaheuristic optimization algorithms. This aligns with recent advancements in educational technology, which emphasize that interactive digital games should transition towards fostering computational thinking and algorithmic problem-solving rather than mere visual engagement (Anggraini et al., 2025).

Furthermore, the interactive mapping of information and instructional scaffolding. Progressing incrementally from basic Traveling Salesman Problem (TSP) to Capacitated Vehicle Routing Problem (CVRP) ensured that students were not cognitively overwhelmed. When compared to previous studies that largely functioned as descriptive scenarios without demanding rigid mathematical validation, our gamified simulation embeds strict algorithmic verification within the user interface. This ensures students do not merely understand the overarching concept of logistics, but also master the mathematical efficiency and accuracy behind it.

This structural success and the resulting error reduction can be deeply understood through multiple interconnected theoretical lenses. First, the incremental progression from basic routing up to complex constraints maps directly onto Csikszentmihalyi (1990)'s Flow Theory. By structuring the simulation into distinct, ascending operations research levels, the game ensured that problem difficulty scaled symmetrically with the students' growing analytical skills. This careful balancing act kept participants within their optimal cognitive "flow channel," effectively mitigating the academic anxiety or boredom often triggered by abstract logistics models.

Second, the iterative behavior driven by real-time feedback aligns heavily with Kolb (2014) Experiential Learning Theory. The simulation interface inherently guides students through a complete experiential loop: they execute a manual routing choice (concrete experience), observe their error deviations immediately (reflective observation), decipher the underlying algorithmic logic by looking at the optimal solution path (abstract conceptualization), and instantly apply their refined strategy to the next randomized problem coordinate set (active experimentation). This continuous cognitive cycle directly accounts for the dramatic reduction in mean penalty scores from 17.88 down to 10.53 ($p < 0.001$).

Furthermore, the sharp post-intervention uptick observed across all motivational dimensions strongly reinforces the core tenets of Self-Determination Theory (Deci & Ryan, 2000) and Constructivist Learning Theory (Piaget, 1952; Vygotsky & Cole, 1978). The simulation's open grid interface granted students a high level of autonomy, while the immediate localized penalty calculations provided objective competence feedback. This combination created the ideal psychological conditions to transform a standard classroom task into an engaging, self-directed learning experience. By measuring these specific shifts in knowledge acquisition and learner engagement, this study successfully fulfills the baseline parameters of Kirkpatrick (1996)'s Evaluation Principles, confirming that gamifying complex operations research tasks yields both measurable cognitive and affective gains.

Despite the positive results, this study acknowledges several methodological limitations that should be considered explicitly in interpreting the findings. First, the absence of a control group makes it challenging to entirely isolate the game's effect from standard instructional maturation over the three-week period. Second, the sample size was relatively small (N=24) and limited to a single cohort, which may restrict the broader generalizability of the findings across different demographics. Third, there is a potential internal validity threat regarding the testing effect; students' growing familiarity with the game's interface by the third week might have contributed slightly to their improved performance, independent of their actual grasp of the routing algorithms. Future implementations should address these limitations by incorporating control groups and expanding the participant cohort.

CONCLUSION

This research concludes that a gamified transportation simulation, characterized by scaffolded complexity and dynamic algorithmic penalty scoring, significantly improves both student comprehension and motivation in learning complex logistics routing problems. Theoretically, the study extends constructivist learning by demonstrating how competitive, real-time algorithmic feedback can solidify abstract mathematical understanding. Practically, it provides educators with a validated, interactive tool to boost student engagement in technical engineering courses. Future research should address current limitations by utilizing larger sample sizes, incorporating control groups, and employing rigorous statistical assumption testing or non-parametric methods to strengthen empirical validity.

ACKNOWLEDGEMENT

This project was supported by Telkom University in the "Hibah PTK" Research Grant 2024, particularly the Logistics Engineering Bachelor Program, which provided academic and logistical support throughout the research. We would also like to thank the students who participated in the pilot testing and feedback sessions, whose contributions were invaluable to the development and refinement of the simulation game.

REFERENCES

Abasian, F., Rönnqvist, M., Marier, P., & Fjeld, D. (2020). Game the transportation game. *INFORMS Transactions on Education*, *21*(1), 52–63. https://doi.org/10.1287/ited.2019.0223

Anggraini, D. N., Komalasari, K., Sopianingsih, P., Insani, N. N., & Sudrajat, F. A. (2025). AI-based interactive digital game development in social studies learning to enhance students' computational thinking. *Jurnal Inovasi Teknologi Pendidikan*, *12*(4), 468–479. https://doi.org/10.21831/jitp.v12i4.89738

Buulolo, S. (2025). Pengembangan modul pembelajaran IPA berbasis saintifik materi sistem gerak pada manusia Kelas VIII SMP Negeri 1 Aramo. *FAGURU: Jurnal Ilmiah Mahasiswa Keguruan*, *4*(1), 209–221. https://doi.org/10.57094/faguru.v4i1.1589

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.

D'Amours, S., & Rönnqvist, M. (2013). An educational game in collaborative logistics. *INFORMS Transactions on Education*, *13*(2), 102–113. https://doi.org/10.1287/ited.1120.0090

Daroini, A. F., & Alfiana, H. (2022). Kesulitan pembelajaran matematika di masa pandemi: Kebutuhan akan modul untuk belajar mandiri. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *6*(1), 1-19. https://doi.org/10.33603/jnpm.v6i1.4604

Daroini, A. F., Wiryokusumo, I., & Leksono, I. P. (2022). Interaksi manusia dengan komputer: Modul matematika dengan aplikasi geogebra. *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, *7*(2), 429–440. https://doi.org/10.29100/jipi.v7i2.2696

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining" gamification". *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, (pp. 9–15). ACM. https://doi.org/10.1145/2181037.2181040

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage Publications.

Fjeld, D., & Hedlinger, C. (2005). The transport game-a tool for teaching the basics of transport decision proficiency. *International Journal of Forest Engineering*, *16*(2), 57–64. https://doi.org/10.1080/14942119.2005.10702514

Gaudron, A., Tamayo, S., & de La Fortelle, A. (2019). Interactive simulation to explore urban distribution schemes. *Transportation Research Procedia*, *37*, 75–82. https://doi.org/10.1016/j.trpro.2018.12.168

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis*. Cengage Learning.

Hakim, F. F., Friatmojo, E. K., Taurano, G. A., & Wijaya, H. A. (2022). Aplikasi gamifikasi peralatan konstruksi untuk pembelajaran jarak jauh pada masa pandemi. *Jurnal Inovasi Teknologi Pendidikan*, *9*(1), 61–76. https://doi.org/10.21831/jitp.v9i1.45012

Kirkpatrick, D. (1996). Great ideas revisited: Revisiting Kirkpatrick's four-level-model. *Training and Development*, *50*(1), 54-57. https://www.proquest.com/docview/227011695?sourcetype=Trade%20Journals

Klock, A. C. K., Wallius, E., & Hamari, J. (2021). Gamification in freight transportation: extant corpus and future agenda. *International Journal of Physical Distribution & Logistics Management*, *51*(7), 685–710. https://doi.org/10.1108/IJPDLM-04-2020-0103

Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamification research. *International Journal of Information Management*, *45*, 191–210. https://doi.org/10.1016/j.ijinfomgt.2018.10.013

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kourounioti, I., Kurapati, S., Lukosch, H., Tavasszy, L., & Verbraeck, A. (2018). Simulation games to study transportation issues and solutions: Studies on synchromodality. *Transportation Research Record*, *2672*(44), 72–81. https://doi.org/10.1177/03611981187923

Kullman, N. D., Dudorov, N., Cousineau, M., Mendoza, J. E., & Goodson, J. C. (2025). Gamifying the vehicle routing problem with stochastic requests. *INFORMS Journal on Computing*. https://doi.org/10.1287/ijoc.2024.0838

Majuri, J., Koivisto, J., & Hamari, J. (2018). Gamification of education and learning: A review of empirical literature. *GamiFIN*, (pp. 11–19). GamiFin. file:///D:/paper2.pdf

Piaget, J. (1952). *The origins of intelligence in children*. (M. Cook, Trans.). W. W. Norton & Company. https://doi.org/10.1037/11494-000

Rahman, A. Z., Dwiyanti, V., & Okitasari, H. (2026). Transformasi pembelajaran logistik: Integrasi gamification dan kecerdasan buatan dalam aplikasi mobile learning. *Seminar Nasional Pendidikan Vokasional*, *1*(1), 93–100. https://proceedings.upi.edu/senavok/article/view/112

Rahmat, R. F., Mursyida, L., Rizal, F., Krismadinata, K., & Yunus, Y. (2019). Pengembangan media pembelajaran berbasis mobile learning pada mata pelajaran simulasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *6*(2), 116–126. https://doi.org/10.21831/jitp.v6i2.27414

Romero, M., Lepage, A., & Lille, B. (2017). Computational thinking development through creative programming in higher education. *International Journal of Educational Technology in Higher Education*, *14*(42), 1-15. https://doi.org/10.1186/s41239-017-0080-z

Sriyunianti, F., Handayani, D., Frima, R., & Yentifa, A. (2022). Analisa kesulitan dan kebutuhan modul pembelajaran secara mandiri. *Akuntansi dan Manajemen*, *17*(2), 17–27. https://doi.org/10.30630/jam.v17i2.187

Tasya, E. L., Hafiz, M., & Musyrifah, E. (2023). Kemampuan berpikir kritis matematis siswa dalam menyelesaikan masalah trigonometri ditinjau dari kecemasan matematisnya. *FIBONACCI: Jurnal Pendidikan Matematika dan Matematika*, *9*(2), 207–218. https://doi.org/10.24853/fbc.9.2.207-218

Tiari, I., Zulkardi, Z., & Siahaan, S. M. (2020). Pengembangan e-learning berbasis chamilo pada pembelajaran simulasi dan komunikasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *7*(1), 1–11. https://doi.org/10.21831/jitp.v6i2.28490

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.

JURNAL INOVASI TEKNOLOGI PENDIDIKAN

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (184-193)
Online: http://journal.uny.ac.id/index.php/jitp

IPTPI Ikatan Profesi Teknologi Pendidikan Indonesia
APS-TPI

Designing ecobalance: A web-based learning product for enhancing climate change literacy and environmental awareness

Nofita Ikayanti*, Ratna Komala, Diana Vivanti Sigit
Universitas Negeri Jakarta, Indonesia.
***** Corresponding Author. E-mail: nofitaikayanti@gmail.com

ARTICLE INFO

Article History
Received:
25 December 2025;
Revised:
18 June 2026;
Accepted:
18 June 2026;
Available online:
30 June 2026.

Keywords
Climate change;
Ecobalance website;
Environmental awareness

ABSTRACT

Climate change is one of the most pressing global challenges affecting human life. Therefore, students need climate change literacy and environmental awareness to support environmental sustainability. This study aimed to develop the Ecobalance website as a learning medium to enhance both competencies. The research employed the Educational Design Research (EDR) approach using the ADDIE model, consisting of the Analysis, Design, Development, Implementation, and Evaluation stages. The participants were 60 tenth-grade students, including 30 students in the experimental class and 30 in the control class, selected through purposive sampling. Data were collected using questionnaires and tests. The Ecobalance website achieved feasibility scores of 90.1%, 90.63%, and 86.67% from material experts, media experts, and students, respectively, indicating that it was "Very Feasible." The implementation produced N-gain scores of 70.95% for climate change literacy and 62.54% for environmental awareness, demonstrating its effectiveness compared with conventional learning. These findings indicate that the Ecobalance website is an effective digital learning medium for environmental education. Future research should examine its long-term impact on students' environmental behavior and evaluate its implementation across different educational levels and learning contexts to assess its broader effectiveness and scalability.

How to cite:
Ikayanti, N., Komala, R., & Sigit, D. V. (2026). Designing Ecobalance: A web-based learning product for enhancing climate change literacy and environmental awareness. *Jurnal Inovasi Teknologi Pendidikan, 13*(1), 184-193. https://doi.org/10.21831/jitp.v13i2.94066

INTRODUCTION

The rapid growth of the global population has intensified anthropogenic activities that contribute significantly to greenhouse gas emissions and global climate change (Sagena et al., 2022; Setiani, 2020). Climate change has become a critical global issue due to its extensive impacts on environmental sustainability and human life (Winarno, 2019). In response to this challenge, students hold strategic potential as agents of change in promoting pro-environmental behavior through education (Tareze et al., 2022). However, several studies indicate that students' environmental awareness remains at a relatively low level, as many have not been actively involved in concrete environmental actions despite having basic environmental knowledge and attitudes (Moody-Marshall, 2023; Habibah & Irawan, 2023; Aisyah et al., 2024).

Iin addition to environmental awareness, climate change literacy is an essential competency for encouraging meaningful action toward sustainability (Haidar et al., 2023). Climate literacy

encompasses understanding the causes, impacts, and mitigation strategies of climate change (Supratiningsih et al., 2023). Nevertheless, students' climate literacy in several regions remains at a basic level, with limited ability to connect global climate issues to local contexts (Haidar et al., 2023). Needs analysis further indicates that a significant proportion of students have limited exposure to reliable climate information and mostly rely on social media as their main source. This condition highlights the urgent need for innovative learning media that can support authentic, contextual, and action-oriented learning experiences (Luthfia, 2019).

Web-based learning media offer strong potential to enhance students' independent learning and literacy engagement through interactive and accessible features (Dimyati et al., 2024; Hekmah et al., 2019). However, most learning practices still rely on conventional, one-way instructional media. To address this gap, this study develops the Ecobalance website, a project-based digital learning platform that integrates climate change education and environmental awareness, complemented by a recycle market feature to encourage real-world environmental action. Previous studies have demonstrated the effectiveness of technology-based learning media in improving students' learning outcomes. Fitriyah et al., (2021) developed learning media using the ADDIE model and reported that the product achieved high feasibility based on expert validation and student responses. Likewise, Meryantie et al., (2025) found that technology-supported learning effectively enhanced students' eco-literacy through meaningful learning experiences. In addition, Kumar et al., (2023) reported that web-based climate change education significantly improved students' climate change literacy.

However, these studies mainly focused on either digital learning media development, climate change literacy, or environmental literacy separately. Few studies have integrated climate change literacy and environmental awareness into a single interactive web-based learning platform for senior high school students. Therefore, this study contributes to the field of environmental education by developing and evaluating the Ecobalance website using the Educational Design Research (EDR) approach. The study provides an empirically validated web-based learning model that integrates climate change literacy and environmental awareness, and demonstrates its effectiveness in improving students' learning outcomes. In addition, this study is expected to contribute to the development of innovative digital learning design that can be adapted in other environmental education contexts. Furthermore, the findings may serve as a reference for educators in integrating technology-based learning with sustainability-oriented competencies in secondary education.

METHOD

This study employed an AI research and development (R&D) approach using the Educational Design Research (EDR) framework with the ADDIE model, which consists of five stages: analyze, design, development, implementation, and evaluation (Branch, 2009). The product developed in this study was a project-based learning website named Ecobalance, designed as an alternative digital learning medium for climate change topics. The research was conducted from January to May 2025 at Islamic Village Private High School, Tangerang Regency, Banten Province, Indonesia. The research participants consisted of 60 tenth-grade students, two biology teachers, and three experts, including an AI media expert, an AI subject matter expert, and an AI language expert for product validation purposes. The school was selected using purposive sampling, while the experimental and control classes were determined using simple random sampling. Class X.2 was assigned as the experimental group and class X.3 as the control group, with each class consisting of 30 students based on the Slovin formula calculation. The effectiveness of the product was tested using a control group pretest–posttest experimental design. Both groups were given a pretest before the implementation of the learning treatment and a posttest after the treatment. The experimental group received learning using the Ecobalance website integrated with the project-based learning model, while the control group was taught using PowerPoint media with the problem-based learning model. The dependent variables in this study were students' climate change literacy and environmental awareness. This study employed the Educational Design Research (EDR) approach with the ADDIE development model to systematically develop and evaluate the Ecobalance website. The research

process followed five main stages: analysis, design, development, implementation, and evaluation. The overall procedure is illustrated in the following flowchart Figure1.

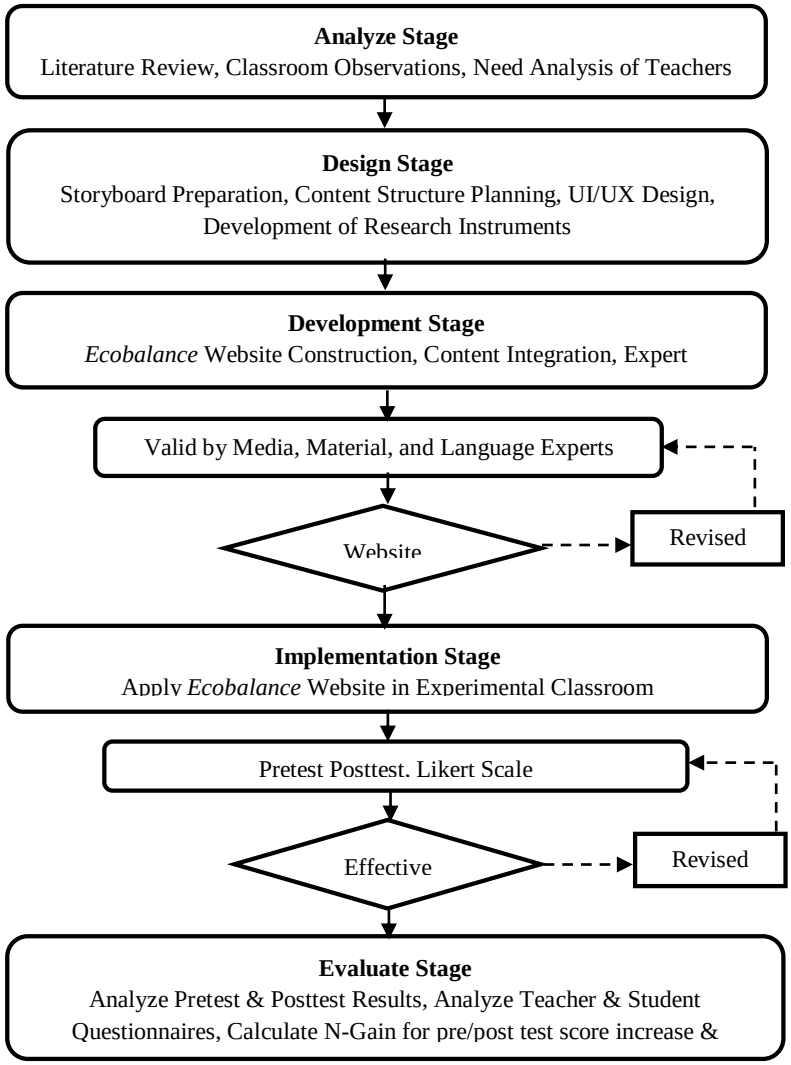

Figure 1. ADDIE Model Procedure Flowchart

Based on the research procedure shown in the flowchart, several data collection instruments were developed and used to gather information at each stage of the study, including analysis, development, implementation, and evaluation. The details of the data collection instruments are presented in the following Table 1.

Table 1. Data Collection Instruments

No.	Technique	Instrument	Assessment Criteria
1	Need Analyze	Questionnaire	Students' and teachers' perceptions of learning and learning media
2	Learning Material Feasibility	Material expert questionnaire	Content suitability and presentation feasibility
		Media expert questionnaire	Language components, visual design, and presentation quality
		Teacher and student questionnaire	Content quality, design, usefulness, and product effectiveness
3	Instrument Feasibility for Climate Change Literacy and	Climate change literacy test and environmental awareness questionnaire	Validity and reliability testing

No.	Technique	Instrument	Assessment Criteria
	Environmental Awareness		
4	Learning Media Implementation Results	Pretest and posttest instruments	Descriptive analysis, assumption testing, and effectiveness testing (N-gain)
5	Student and Teacher Responses	Questionnaire	User responses toward product use

To ensure the quality of the research instruments, validity and reliability testing were conducted on the instruments used to measure climate change literacy and environmental awareness. The results of the validity and reliability analysis are presented in the following Table 2.

Table 2. Instrument Validation Result

No.	Environmental Awareness Instrument			Climate Change Literacy Instrument		
	Indicator	**Item Number Validity**	**Reliability**	**Indicator**	**Item Number Validity**	**Reliability**
1	Cognitive	1,2,3,4,5, 6*,7*,8	Cronbach's Alpha 0.927 ≥ 0.6 (Reliable)	Knowledge about climate change	2*,4*,6,18, 19,25,28*	Cronbach's Alpha 0.927 ≥ 0.6 (Reliable)
2	Affective	9,10,11,12, 13*,14,15		Understanding about impacts and threats of climate change	1,3*,7,9, 10,20,21*, 22,23,24,29	
3	Conative	16,17,18*, 19,20,21, 22*,23,24		Motivation to make accurate decisions to implement mitigation and adaptive solutions to the climate crisis	5*,8*,11, 12,13,14,15, 16,17,26, 27,30	
4	Active	25,26,27 28,29,30				

Note (*): Invalid Instrument

Based on the results of the validity and reliability testing, the research instruments were considered appropriate for use in data collection. Therefore, the validated instruments were subsequently implemented in the experimental phase to examine the effectiveness of the Ecobalance website in improving students' climate change literacy and environmental awareness. The results of the implementation are presented and discussed in the following section.

RESULTS AND DISCUSSION

Results

The results of the Ecobalance website development are presented according to the five stages of the ADDIE model. At the analysis stage, a needs assessment was conducted involving 50 eleventh-grade students and three biology teachers. The findings revealed that 57% of students considered climate change material to be very important, and none perceived it as unimportant, indicating a high level of awareness of its relevance. However, only 14% of students reported having a strong understanding of the causes and impacts of climate change, and 82% were not actively involved in environmental action. In terms of learning media, 78% of students stated that PowerPoint was the most frequently used medium, while only 2% reported the use of websites. Most students relied on social media as their main source of climate information (58%), although 26% accessed credible

environmental organization websites. Moreover, 60% of students strongly expected the Ecobalance website to support their learning. Teachers unanimously (100%) agreed on the importance of climate change education, yet 66.7% reported that students' engagement and understanding remained low. Teachers also emphasized the need for visually attractive, content-rich, and context-based digital learning media. These findings confirmed the urgency of developing a project-based digital learning platform to improve climate change literacy and environmental awareness. The results of the needs analysis can be seen in Table 3.

Table 3. Needs Assessment Results

No.	Indicator	Response Category	Percentage (%)
1	Importance of climate change topic	Very Important	57%
		Other Responses	43%
2	Understanding of climate change topic	Less Understanding	14%
		Good Understanding	86%
3	Involvement in environmental change actions	Less Involved	82%
		Very Involved	12%
4	Learning media frequently used by teachers for climate change issues	Website	2%
		Other Media	98%
5	Need for the Ecobalance website to support climate change	Very Important	60%
		Other Responses	40%

At the design stage, the Ecobalance website was systematically planned based on the needs analysis results. The instructional design was aligned with the Project-Based Learning (PjBL) model to promote context- and action-oriented learning. The website structure was conceptualized through storyboards, learning flow design, and navigation mapping. Four main features were designed: EcoInfo for climate information and news, EcoProject for weekly environmental action projects, EcoShop for marketing recycled student products, and EcoQuiz for evaluation. At this stage, research instruments were also developed and validated. The climate change literacy instrument consisted of 20 two-tier multiple-choice items, while the environmental awareness instrument consisted of 25 Likert-scale statements. Validity testing showed that several items were excluded due to low significance values, while reliability testing using Cronbach's Alpha showed excellent reliability coefficients of 0.908 for climate literacy and 0.927 for environmental awareness. The display of the EcoInfo, EcoProject, EcoShop, and EcoQuiz features can be seen in Figure 2.

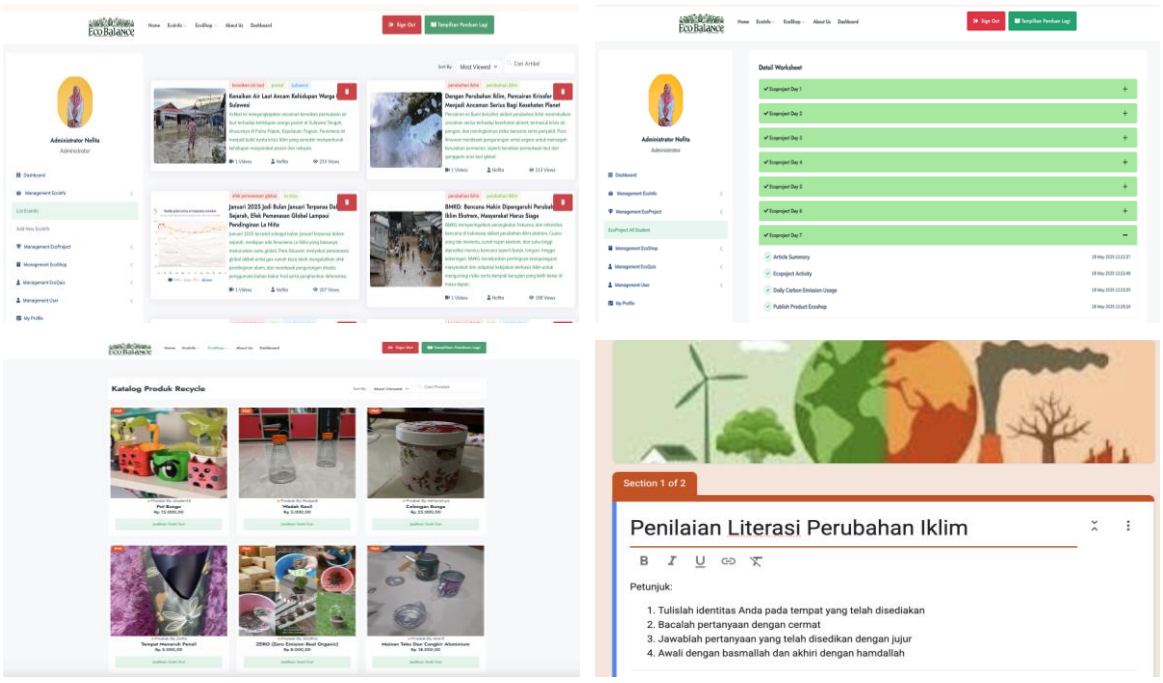

Figure 2. EcoInfo, EcoProject, EcoShop, and EcoQuiz Feature Display

At the development Stage, the Ecobalance website was fully constructed using web programming technologies and online server hosting. All designed features were implemented according to the PBL syntax. Expert validation was conducted involving media experts, subject matter experts, and language experts. The material expert validation yielded an average feasibility score of 90.1%, categorized as "very feasible". Media expert validation resulted in a score of 90.63%, also categorized as "very feasible". The expert validation results are shown in Table 4.

Table 4. Expert Validation Result

No.	Material Expert Validation			Learning Media Expert Validation		
	Indicator	**Average**	**Description**	**Indicator**	**Average**	**Description**
1	Material Substance	93.7	Very Feasible	Language	87.5	Very Feasible
2	Material Presentation	97.5	Very Feasible	Visual Display	92.2	Very Feasible
3	Learning Design	85.4	Very Feasible	Overall Display	92.5	Very Feasible
4	Media Effects on Learning	93.7	Very Feasible			
Score (%)		**90.1**	**Very Feasible**	**Score (%)**	**90.63**	**Very Feasible**

During the development phase, product trials were conducted involving biology teachers and students. The trial with biology teachers resulted in a feasibility score of 93%, indicating a very high level of suitability. Meanwhile, a small-group trial involving 15 students yielded an average score of 86.67%, reflecting excellent usability and perceived learning benefits. Revisions were implemented based on feedback from experts and users, focusing on improving the clarity of learning objectives, enriching the content, enhancing visual representation, and refining usability guidelines. The results of the product trials with biology teachers and students are presented in Table 5.

Table 5. Biology Teachers & Students Assessment Results

No.	Biology Teachers Assessment			Students Assessment		
	Indicator	**Average**	**Description**	**Indicator**	**Average**	**Descripti on**
1	Ease of Understanding	96.9	Very Feasible	Understanding the Material	88.67	Very Feasible
2	Product Usage	87.5	Very Feasible	Product Usage	87.89	Very Feasible
3	Product Appearance	100	Very Feasible	Product Appearance	84.38	Very Feasible
4	Product Benefits	87.5	Very Feasible	Product Benefits	85.42	Very Feasible
Score (%)		**93**	**Very Feasible**	**Score (%)**	**86.67**	**Very Feasible**

At the implementation stage, the Ecobalance website was applied in an experimental class consisting of 30 tenth-grade students, while another 30 students in a control class learned using PowerPoint-based instruction. Both classes completed pretests and posttests measuring climate change literacy and environmental awareness. Descriptive analysis processed using SPSS showed substantial improvements in the experimental group compared to the control group. The mean literacy score of the experimental class increased from 58.33 to 88.87, while the control group improved from 60.60 to 77.70. The N-gain for the experimental group reached 70.95%, categorized as moderately effective, compared to 41.02% in the control group. Environmental awareness scores also showed a greater improvement in the experimental class, with posttest scores reaching 92.17 compared to 85.70 in the control group. The descriptive test results are presented in Table 6.

Table 6. The Descriptive Test Results

No.	Analysis	Class Category	Climate Change Literacy		Environmental Awareness	
			Pretest	**Posttest**	**Pretest**	**Posttest**
1	Number of Samples	Experiment	30	30	30	30
		Control	30	30	30	30
2	Mean	Experiment	58.33	88.87	78.97	92.17
		Control	60.60	77.70	74.60	85.70
3	Standard Deviation	Experiment	10.58	5.11	4.57	4.3
		Control	8.57	4.96	4.63	3.58
4	Lowest Value	Experiment	38	80	70	82

No.	Analysis	Class Category	Climate Change Literacy		Environmental Awareness	
			Pretest	Posttest	Pretest	Posttest
		Control	48	65	65	74
5	Highest Value	Experiment	78	98	90	98
		Control	75	90	81	92
6	Variant	Experiment	111.95	26.18	20.93	18.55
		Control	73.55	24.63	21.49	14.83
7	N-gain	Experiment	70.95%		62.54%	
		Control	41.02%		42.12%	

At the final evaluation stage, summative evaluation was conducted based on the entire development, validation, and implementation process. The results demonstrated that the Ecobailaince website met the criteria of a highly feasible, effective, and pedagogically appropriate digital learning medium. Final refinements included improving visual appearance, optimizing interactive features, and distributing direct access links to teachers and students. Overall, the Ecobalance website proved to be a valid and effective project-based digital learning innovation for enhancing climate change literacy and environmental awareness among senior high school students.

Discussion

This study employed the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) to guide the systematic development of the Ecobalance website for climate change education. The ADDIE model has been widely applied in educational media development due to its structured yet flexible nature, enabling continuous refinement based on learner needs and formative feedback (Branch, 2009). Previous studies confirm that AI-based digital learning designs contribute to improved learning engagement and conceptual understanding when each phase is implemented iteratively and coherently (Dilaines et al., 2024). The needs analysis revealed a clear gap between students' learning preferences and instructional practices in schools. While most students perceived climate change as a highly important topic, they primarily accessed related information through social media platforms. In contrast, teachers relied predominantly on textbooks and static presentation media. This discrepancy aligns with findings by Moriska & Hanif (2024), who reported that teacher-centered use of conventional media limits students' active engagement and critical processing of environmental issues. Moreover, reliance on social media as an information source has been associated with increased exposure to misinformation and fragmented scientific understanding, particularly in climate-related topics (Berger et al., 2023; Essien et al., 2025). These findings highlight the need for an instructional intervention that integrates accessible digital media with scientifically validated content.

Based on the analysis results, the learning design was structured around Project-Based Learning (PjBL), supported by reliable assessment instruments for climate change literacy and environmental awareness. PjBL has been widely recognized as an effective approach for environmental education because it engages learners in authentic problem-solving and contextualized learning experiences (Lopes & Palacios, 2024). The instruments developed in this study demonstrated excellent internal consistency, with Cronbach's alpha values exceeding 0.90, indicating strong reliability. Such reliability levels are consistent with standards in educational measurement, where alpha values above 0.70 indicate acceptable reliability and values above 0.90 reflect excellent consistency (Taber, 2016; Singh, 2024). Additionally, the use of two-tier diagnostic items strengthened the measurement of climate literacy by capturing both conceptual understanding and potential misconceptions, as recommended in science education research (Taber, 2024). During the development phase, the Ecobalance website was constructed by integrating multimedia learning materials, interactive quizzes, and project-based environmental activities. Expert validation results from both content and media specialists indicated that the website met high feasibility standards, with average scores above 90%. Similar validation outcomes have been reported in previous studies, where digital learning media achieving feasibility scores above 85% were categorized as highly valid and ready for classroom use (Devi & Rusdinal, 2023; Mahmuzah et al., 2024). Limited trials involving biology teachers and small groups of students further demonstrated that the website was practical, easy to use, and pedagogically appropriate. These findings support earlier research by Irfan

et al., (2024), which emphasized the importance of iterative trials in improving the usability and effectiveness of digital learning media.

The implementation of the Ecobalance website in the experimental class resulted in higher descriptive gains in both climate change literacy and environmental awareness compared to the control class. Based on pretest and posttest results, the experimental group achieved N-gain values of 70.95% for climate change literacy and 62.54% for environmental awareness, both categorized as moderately effective. In contrast, the control group showed lower N-gain values, indicating less substantial improvement. These results are consistent with previous studies demonstrating that project-based digital learning environments yield higher learning gains than conventional instruction, particularly in sustainability-related topics (Anggraini et al., 2022). The descriptive analysis of indicator-level improvements showed that students in the experimental group experienced notable gains not only in cognitive aspects but also in affective and cognitive dimensions of environmental awareness. The greatest improvement was observed in the cognitive dimension, suggesting that students were more inclined to engage in pro-environmental actions after participating in project-based activities through the Ecobalance platform. This finding aligns with Bramwell-Lalor et al., (2020), who reported that experiential and project-based environmental learning effectively fosters behavioral intentions and real-world environmental action. Overall, the evaluation results indicate that the Ecobalance website successfully supports meaningful learning by integrating scientific literacy, emotional engagement, and action-oriented environmental education.

CONCLUSION

This study concludes that the Ecobalance website developed through the ADDIE model and implemented using a project-based learning approach is valid, feasible, and effective in improving students' climate change literacy and environmental awareness at the senior high school level. The findings consistently show that students who learned using Ecobalance achieved significantly higher gains in both literacy and environmental awareness compared to those who learned through conventional problem-based PowerPoint media, as supported by descriptive analysis with N-gain scores. These results confirm that integrating digital learning media with real-world environmental action through project-based learning can strengthen students' conceptual understanding, attitudes, and behavioral intentions toward climate change issues. Based on these findings, the Ecobalance website can be operationally implemented as an alternative instructional medium in climate change learning to support interactive, contextual, and action-oriented science education. Teachers are encouraged to use Ecobalance to facilitate student projects related to carbon footprint reduction and environmental campaigns, while schools may adopt it as part of sustainable education programs. Furthermore, future research is recommended to investigate the long-term impact of the Ecobalance website on students' climate change literacy, environmental awareness, and pro-environmental behaviors. Future studies may also integrate advanced interactive features, such as gamification, personalized learning pathways, and adaptive feedback, and evaluate their effectiveness across different schools and educational levels.

ACKNOWLEDGEMENT

The author would like to express sincere gratitude to the research supervisors, Prof. Dr. Ratna Komala, M.Si., and Prof. Dr. Diana Vivanti Sigit, M.Si., for their valuable guidance throughout this study. Appreciation is also extended to Dr. Hanum Isfaeni, M.Si., and Dr. Rizhal Hendi Ristanto, M.Pd., for their constructive feedback as examiners. The author thanks the lecturers of the Biology Education Program, Universitas Negeri Yogyakarta, for their academic support. Special thanks are addressed to Farida Susantina, M.Pd., and Nunung Iswatun Chasanah, M.Si., for their expertise in validating the developed product. Gratitude is also extended to the principal, teachers, and students of Islamic Village Private High School for their cooperation and participation in this research. The author also acknowledges the support from family and colleagues who contributed to the completion of this research.

REFERENCES

Aisyah, A., Putri, K. A. J. A., & Firjanah, L. (2024). Pentingnya membangun kesadaran lingkungan melalui pembelajaran PKN di sekolah dasar guna membentuk karakter peduli lingkungan pada siswa. *Jurnal Pendidikan Guru Sekolah Dasar*, *1*(3), 11-20. https://doi.org/10.47134/pgsd.v1i3.529

Anggraini, D., Abdurrahman, & Herlina, K. (2022). Development of learning program based on multiple representations integrated with PJBL George Lucas and STEM to foster students' sustainability literacy. *Jurnal Pendidikan Fisika dan Keilmuan*, *8*(2), 253–279. https://doi.org/10.25273/jpfk.v8i2.15660

Berger, L., Marie, L., Anna, K., Felix, M., & Johannes, M. (2023). Debunking "Fake News" on social media: Short-term and longer-term effects of fact-checking and media literacy interventions. *ECON tribute Discussion*, Paper No. 262. https://share.google/xuSseBGhfV2cGhowP

Bramwell-Lalor, S., Kelly, K., Ferguson, T., Gentles, C. H., & Roofe, C. (2020). Project-based learning for environmental sustainability action. *Southern African Journal of Environmental Education*, *36*(1), 57-71. https://doi.org/10.4314/sajee.v36i1.10

Branch, R. M. (2009). *Instructional design*. In Digital Learning: The Key Concepts. Springer International Publishing. https://doi.org/10.4324/9780429425240-105

Devi, M. Y., & Rusdinal. (2023). Validation of digital learning media to improve the basic literacy skills of low-grade elementary school students. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *7(*1), 119–129. https://doi.org/10.31004/obsesi.v7i1.3713

Dilaines, L. E., Astuti, E., & Yusdita, E. E. (2024). Improving student learning outcomes through accurate online modules with the ADDIE model. *Journal of Education Technology*, *8*(2), 275–286. https://doi.org/10.23887/jet.v8i2.67576

Dimyati, M., Karim, J., Jabbar, A., Amrulloh, A., Irfani, M., & Budi, S. (2024). Desain dan implementasi platform edukasi berbasis website menggunakan extreme programming. *Jurnal Sistem dan Teknologi Informas*i, *12*(3), 461-470. https://doi.org/10.26418/justin.v12i3.77402

Essien, E. O. (2025). Climate change disinformation on social media: A meta-synthesis on epistemic welfare in the post-truth era. *Soc. Sci*, *14*(5), 1-34. https://doi.org/10.3390/socsci14050304

Fitriyah, I., Wiyokusumo, I., & Leksono, I. P. (2021). Pengembangan media pembelajaran Prezi dengan model ADDIE, simulasi dan komunikasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 84–97. https://doi.org/10.21831/jitp.v8i1.42221

Habibah, M., & Irawan, F. A. (2023). Tingkat kesadaran lingkungan siswa dalam menghadapi pemanasan global dalam kegiatan literasi bumiku program kampus mengajar 4. *Jurnal Pendidikan Geosfer*, *8*(1), 17–28. https://doi.org/10.24815/jpg.v8i1.29167

Haidar, D. A., Prastiti, T. D., Novianti, I., Wahyuningrum, E., Dafik, D., & Ridlo, Z. R. (2023). Aktivitas pembelajaran RBL dengan pendekatan STEAM: Pemanfaatan toples kaca bekas dalam pengembangan terarium dengan konsep keseimbangan ekosistem berbantuan games simulasi untuk meningkatkan literasi perubahan iklim. *In Ebook CGANT Universitas Jember* 113–140. https://www.scribd.com/document/736242672/30-140-1-PB

Hekmah, N., Wilujeng, I., & Suryadarma, I. G. P. (2019). Web-lembar kerja siswa IPA terintegrasi lingkungan untuk meningkatkan literasi lingkungan siswa. *Journal Innovations in Pedagogy*, *5*(2), 129–138. https://doi.org/10.21831/jipi.v5i2.25402

Irfan, Febriati, F., Mawarni, S., & Hakim, A. (2024). Enhancing higher education through interactive microlearning e-modules. *Indonesian Journal of Educational Technology*, *3*(1), 1–9. https://doi.org/10.26858/ijet.v3i1.2180

Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Emygdio, A.P.M., Abhijith, K.V., Kukadia, V., Holmes, K., Pfautsch, S. (2023). Using empirical science education in schools to improve climate change literacy. *Renewable and Sustainable Energy Reviews*, *178*(1), 1-13. https://doi.org/10.1016/j.rser.2023.113232

Luthfia, A. R. (2019). Penguatan literasi perubahan iklim di kalangan remaja. *Jurnal Abadimas Adi Buana*, *3*(1), 39–42. https://doi.org/10.36456/abadimas.v3.i1.a1941

Lopes, J. A., & Palacios, F. J. P. (2024). Effects of AI project-based learning methodology on environmental awareness of secondary school students. *International Journal of Instruction*, *17*(1), 1–22. https://e-iji.net/ats/index.php/pub/article/view/492

Mahmuzah, R., Zahara, Y., Ningtiyas, F. A., Sinaga, N. A., Saragih, N. J., & Aufa, Z. Y. (2024). Analisis validitas media pembelajaran interaktif berbasis Android terintegrasi Smart Apps Creator bermuatan literasi numerasi. *Journal of Scientific Information and Educational Creativity*, *25*(2), 332–343. https://doi.org/10.30649/fisheries.v2i2.43

Meryantie, A., Huda, N., Tobing, V. M. T. L., & Muhajir. (2025). Implementation of TBL with constructivist and discovery learning approaches to enhance eco-literacy of homeschooling students. *Jurnal Inovasi Teknologi Pendidikan*, *12*(3), 307–316. https://doi.org/10.21831/jitp.v12i3.85855

Moody-Marshall, R. (2023). An investigation of environmental awareness and practice among a sample of undergraduate students in Belize. *Environmental Education Research*, *29*(7), 911–928. https://doi.org/10.1080/13504622.2022.2079613

Moriska, A., & Hanif, M. (2024). Interactive learning multimedia articulate storyline is an alternative medium to improve elementary students' critical thinking skills. *Journal Ilmiah Sekolah Dasar*, *8*(2), 258–269. https://doi.org/10.23887/jisd.v8i2.65310

Sagena, U. W., Panjaitan, O., Azizsyah, S. N., Hasyim, M., Dino, Mohd., & Sharifuddin, K. (2022). SDGs class for kids: edukasi kesadaran energi dan lingkungan kepada pelajar di kawasan IKN Nusantara. *Seminar Nasional Pengabdian Kepada Masyarakat*, 851–858. https://www.researchgate.net/publication/371349726_SDGs_Class_for_Kids_Edukasi_Kesadaran_Energi_dan_Lingkungan_Kepada_Pelajar_di_Kawasan_IKN_Nusantara

Setiani, P. (2020). *Sains perubahan iklim*. Bumi Aksara.

Singh, T. (2024). Reliability in student assessment: Implications for competency-based curriculum. *Indian Journal of Health Sciences and Biomedical Research (KLEU)*, *17*(2), 95-99. https://doi.org/10.4103/kleuhsj.kleuhsj_15_24

Supratiningsih, Dafik, I. H., Agustin, R., Nisviasari, I. L., Mursyidah., & Prihandini, R. M. (2023). Aktifitas pembelajaran RBL dengan pendekatan STEAM memanfaatkan waste paper dalam pembuatan miniatur organ jantung manusia berbantuan Augmented Reality (AR) dalam meningkatkan literasi perubahan iklim siswa. *Pengembangan Literasi Perubahan Iklim Berbasis Machine Learning dengan RBL-STEM*, (pp. 23–42). https://ebook-cgantunej.my.id/index.php/cgant/article/download/24/49

Taber, K. S. (2016). The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Res Sci Educ*, *48*, 1273–1296 https://doi.org/10.1007/s11165-016-9602-2

Tareze, M., Indri Astuti, & Afandi. (2022). Model pembelajaran kolaborasi SDGs dalam pendidikan formal sebagai pengenalan isu global untuk meningkatkan kesadaran sosial peserta didik. *Visipena*, *13*(1), 42–53. https://doi.org/10.46244/visipena.v13i1.1978

Winarno, B. (2019). *Dinamika politik global kontemporer: Teori, aktor, isu dan analisis studi kasus*. Media Pressindo.

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 1, June 2026 (194-212)
Online: http://journal.uny.ac.id/index.php/jitp

Development of a validation system (SVeR) based on the open journal system for testing the validity of learning tools

Safrizal[1] *, Syamsul Bahri[1], Desri Jumiarti[1], Musawer Hakimi[2]
[1] Universitas Islam Negeri Mahmud Yunus Batusangkar, Indonesia.
[2] Samangan University, Afghanistan.
* Corresponding Author. E-mail: safrizal@uinmybatusangkar.ac.id

ARTICLE INFO

Article History
Received:
21 January 2026;
Revised:
19 June 2026;
Accepted:
24 June 2026;
Available online:
30 June 2026.

Keywords
Integrated e-campus; Open journal system; Validation of learning devices; Validation system

ABSTRACT

The prevalence of unvalidated learning tools highlights a critical issue stemming from inefficient manual validation processes. This research addresses this by developing a valid, practical, and effective validation system (SVeR) for learning tools, integrated with an open journal system. Employing the Waterfall development model, the study involved 2 expert validators and 16 lecturers to assess the system's practicality and effectiveness. Data analysis utilized Aiken's V for validity, percentage techniques for practicality, and the kappa moment test for effectiveness. Results indicate SVeR possesses very high validity, with a content validity coefficient of 0.804. Practicality was also very high at 94.31% (convenient category), and effectiveness reached a kappa moment of 0.939, categorized as very high. These findings confirm that SVeR offers excellent validity, practicality, and effectiveness for assessing learning device suitability. Future research should test SVeR across institutions, compare systems, evaluate integration, and expand its applications.

How to cite:
Safrizal et al., (2026). Development of a validation system (SVeR) based on the open journal system for testing the validity of learning tools. *Jurnal Inovasi Teknologi Pendidikan, 13*(2), 194-212. https://doi.org/10.21831/jitp.v13i2.95262

INTRODUCTION

Learning is one of the processes within the scope of education that will determine graduates' achievements and competency standards. As an essential process, learning requires several components to be present to lead to achieving each goal (Aziira et al., 2023; Muhsinin & Fatmawati, 2020). The teacher and the equipment are supporting components that make learning holistic, continuous, and targeted (Firdaus et al., 2023; Helmina et al., 2023). Teachers are important because the learning process will run if the guides and facilitators are appropriate to the scientific field, as with learning tools. Teachers and learning tools are determinants in achieving graduate competency standards at any level of education. They are launched not only at the basic education level but also at the higher education level.

In this case, semester learning plans are mandatory learning tools in higher education units. The obligation to make learning implementation plans in higher education aims to achieve graduate learning achievements reliably (Aziira et al., 2023; Muhsinin & Fatmawati, 2020). The importance of learning plans as one of the tools created by teachers is regulated in National Higher Education

Standards Number 3 of 2020, which states that learning tools (RPS) are semester learning process plans that are prepared for learning activities during one semester to meet the learning outcomes of graduates assigned to subjects. Studying. Apart from that, at several points, it is also mentioned that the RPS preparation process is also regulated in terms of its design so that, in the end, the RPS that will be produced is an RPS that is validated by a group of people who are authorised to assess and validate the RPS.

The RPS validation process ensures that the learning plans prepared meet the graduate learning outcomes assigned to the courses and that the learning process remains on track to realise the Institute's vision by the planned graduate profile. Several studies state that the validation process is carried out to check and measure the accuracy of the learning outcomes assigned to courses (Arikunto, 2012; Ayriza, 2013; Budiastuti & Bandur, 2020; Saputri & Guspatni, 2021). The same thing was also stated: the validation process in the RPS was carried out to assess the extent of accuracy and thoroughness in carrying out its functions to achieve graduate learning outcomes. From the explanation above, it is clear that the validation process for the RPS is essential to make the RPS a tool that can serve as a guide for lecturers in carrying out lectures so that they achieve the expected goals.

Unfortunately, the RPS validation process described above does not correspond to what happens in the field. Based on the survey results from the quality assurance center of the Faculty of Tarbiyah and Teacher Training, Mahmud Yunus State Islamic University, Batusangkar, it was found that only 28% of the RPS were validated from the total number of RPS in the odd semester 2023/2024. Based on the results of interviews conducted by several lecturers, most of the lecturers did not understand the validation flow and the validator team of the RPS they had created. Another finding based on an interview with one of the study program's quality control groups stated that difficulties in corrections were still carried out manually. The return process did not have an easy and effective flow, so the RPS validation process was often not carried out optimally. The discovery of this problem is one of the essential points that must be resolved so that the RPS used can be ensured in measuring the achievement of the burden of Graduate Learning Outcomes imposed on courses.

Problems related to the low number of validated RPS in the Tarbiyah and Teacher Training Faculty, especially in elementary school teacher education study programs, require appropriate solutions to alleviate the problem. Several things can be done, including developing an RPS validation system that is easily accessible to all groups, both the lecturers who create it and the verification team (Munthe et al., 2019; Salamun & Arisandi, 2020). Several related research results state that developing digitally integrated systems, such as websites, effectively solves the problem of validating and collecting documents (Darmini & Putra, 2009; Prastika, 2022). The same research also states that an RPS validation system needs to be created to facilitate the flow of communication between the validator team and users or creators so that it has a clear workflow, meaning that it is necessary to develop a centralized and integrated system (Apriany & Setiawan, 2022; Muslihudin et al., 2019; Nurafni et al., 2022).

The increasing prevalence of unvalidated learning tools underscores a critical need for efficient validation processes, moving beyond manual and often ineffective methods. While prior research has broadly explored the development of digital validation systems (Fajrin et al., 2016; Handayani et al., 2019; Setiawan et al., 2023; Bamary et al., 2022; Foumani & Goudariz, 2021; Kalavaini, 2021; Lialestani et al., 2021). This study distinguishes itself by specifically developing a Learning Tool Validation System (SVeR) based on an Open Journal System (OJS) integrated with the e-campus platform at Universitas Islam Negeri Mahmud Yunus Batusangkar. The novelty of this research lies in its specific contextual implementation and rigorous validation within a defined academic environment, namely UIN (State Islamic University) Mahmud Yunus Batusangkar, coupled with the strategic integration of OJS and e-campus to enhance update efficiency, optimize resource utilization, and ensure ubiquitous accessibility.

To ensure the system's relevance and acceptance, this research involved two expert validators who provided comprehensive assessments of SVeR's content and construct validity, alongside sixteen lecturers from UIN Mahmud Yunus Batusangkar as subjects for practicality and effectiveness testing. The primary focus of these results is to demonstrate that SVeR is not only theoretically valid

but also highly practical and effective in real-world application by lecturers within this specific higher education institution. This approach significantly differentiates the present study from previous works, offering robust empirical evidence for SVeR's viability as an innovative solution for learning tool validation in higher education.

In higher education, the course syllabus—often formally documented as a Semester Learning Plan (Rencana Pembelajaran Semester - RPS)—is a critical document that serves as an academic contract between the instructor and students. It is the primary guide for course delivery. The development of a high-quality syllabus is foundational to creating a learning experience that is structured, measurable, and aligned with the Program Learning Outcomes (PLOs) established by the academic department (Allen, 2004). An effective syllabus extends beyond a mere list of topics; it meticulously details course learning outcomes (CLOs), instructional methods, assessment strategies, and a systematic timeline (Fink, 2013). The process of ensuring the quality and appropriateness of a syllabus before its implementation is known as validation. Syllabus validation involves a review by subject matter experts or a quality assurance team to assess the alignment between program outcomes, course outcomes, instructional materials, and the evaluation system (Fink, 2013). This process ensures that the instructional plan is not only valid in its content but also constructively designed to facilitate student competency development. A well-documented validation process serves as evidence of institutional accountability and is an integral part of the quality assurance cycle in higher education (Biggs & Tang, 2011).

With the advancement of digital technology, numerous academic processes, including scholarly publishing, have migrated to online platforms. Open Journal Systems (OJS) is one of the most widely used web-based journal management platforms globally. Developed by the Public Knowledge Project (PKP), OJS was designed to facilitate the entire editorial workflow online, from author submissions and peer review to editing and final publication (Willinsky, 2005). The primary advantage of OJS lies in its structured and well-documented workflow, enabling editors to assign manuscripts to reviewers, set deadlines, manage revisions, and maintain a complete record of all communications within a centralized dashboard. Its flexibility also allows for customization of various components, including review forms, and its open-source nature has fostered widespread adoption and adaptation for various contexts beyond traditional journal publishing, such as conference management (Stranack, 2006). However, its adaptation as a validation system for academic documents like a course syllabus remains a largely unexplored area.

The validation process for a course syllabus in a university setting shares a striking workflow similarity with the peer-review process of a scholarly journal. In both scenarios, there is an "author" (the instructor developing the syllabus), an "editor" (the head of the department or curriculum team), and a "reviewer" (the validator or quality assurance unit). The instructor uploads a draft syllabus, the editor assigns it to a validator for assessment based on institutionally approved criteria, and the validator provides scores and qualitative feedback, which then forms the basis for the instructor's revisions. Currently, this validation process is often conducted manually using printed forms or disparate digital platforms (e.g., email and Google Forms). This approach frequently presents challenges related to instrument standardization, tracking revision history, and systematic archiving, which can complicate audits and accreditation processes (Biggs & Tang, 2011). The absence of an integrated system can impede the efficiency and transparency of the quality assurance cycle.

Addressing this gap, the present study proposes the adaptation of Open Journal Systems (OJS) into an electronic Validation System (SVeR) for course syllabi. By modifying user roles and customizing the review forms within OJS, the syllabus validation workflow can be managed in a more structured, transparent, and efficient manner. This system is envisioned to document every stage of the validation—from initial draft submission and validator assignment to instrument completion and final approval—within a single, integrated platform. This innovation offers a practical solution for higher education institutions to strengthen their internal quality assurance systems (SPMI) related to instructional planning.

METHOD

The Validation System (SVeR) based on the e-campus integrated open journal system was developed within the research and development (R&D) framework by applying the waterfall model, with four stages: needs analysis, system design, system implementation, and system testing. This system was developed using PHP programming and the Codeigniter framework.

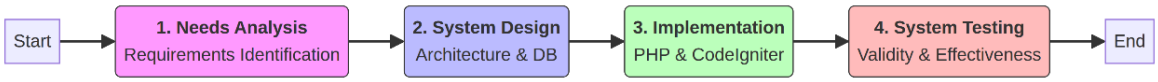

Figure 1. Research Framework

This system design was created to suit user needs so that it is more targeted. The development method is used to develop and measure the validity, feasibility, and effectiveness of the product being developed in this research. Learning is based on an open journal system that is integrated with e-campus. This research involved two primary groups of participants: two media expert validators and 16 lecturers as product trial participants. The media expert validators were selected based on their expertise in educational technology and learning system development to evaluate the feasibility of the developed system. The 16 lecturers were selected using purposive sampling based on specific criteria, namely lecturers who were actively involved in preparing, managing, or validating learning devices and had experience in using academic information systems. These lecturers were directly involved as users of the developed e-RPS Validation System (SVeR) to evaluate its practicality and effectiveness in supporting the learning device validation process. Secondary data sources were obtained from previous research studies on digitalizing academic information systems.

The types of instruments used in this research are interview guides and questionnaires. The interview guide contains several questions for exploring user information and analyzing user needs in the learning device validation process. The data collection instruments used in this study consisted of a semi-structured interview guide, an application validity questionnaire, a practicality questionnaire, and an effectiveness questionnaire. Each instrument was developed according to the objectives and stages of the research. The semi-structured interview guide was used during the needs analysis stage. It was intended to obtain qualitative information regarding the existing RPS validation process, the difficulties experienced by users, the information required during validation, and the expected features of the e-RPS Validation System, hereafter referred to as SVeR.

Table 1. Need Assessment Interview Guide

No.	Aspect Explored	Information Collected
1	Existing Validation Process	Procedures and stages currently used in validating RPS documents
2	User Difficulties	Problems encountered during submission, review, revision, and approval of RPS documents
3	Information Requirements	Information required by users during the RPS validation process
4	System Requirements	Features, menus, notifications, and workflows expected in SVeR
5	User Expectations	Expected benefits, ease of use, and efficiency of the developed system

The application validity questionnaire was administered to expert validators to assess the feasibility of SVeR. The instrument covered three main aspects, namely usefulness, design, and system operation. The questionnaire consisted of 17 items.

Table 2. Validity Questionnaire Blueprint

No.	Aspect	Indicator or statement
1	Usefulness	The OJS-based e-RPS Validation System facilitates the RPS validation process. The system facilitates the input of validated RPS documents into the e-campus platform. The system improves time and work efficiency. The system facilitates the uploading of RPS documents to the e-campus platform.
2	Design	Appropriateness and readability of the font size Appropriateness of the font type

No.	Aspect	Indicator or statement
		Appropriateness of the colour composition
		Appropriateness of the interface and background design
		Clarity of the menus and system navigation
3	System Operation	Ease of understanding the validation format and workflow
		Availability and clarity of system-use instructions
		Availability of a standardized RPS format and validation guidelines
		Ease of understanding the format of information generated by the system
		Ease of logging into the system
		Consistency between the requested input and the system output
		Speed of the system in responding to user requests
		Ease of entering user data and uploading documents

The practicality questionnaire was administered to users after they had operated SVeR. This questionnaire was used to assess whether the developed system could be used easily, efficiently, and conveniently in the actual RPS validation process.

Table 3. Practicality Questionnaire Blueprint

No.	Aspect	Indicator/Statement
1	Correctness	The SVeR based on Open Journal System provides convenience in the RPS validation process.
		The SVeR based on Open Journal System facilitates the input of RPS documents into the e-campus system.
		The use of SVeR based on Open Journal System is appropriate for improving the effectiveness of the RPS validation process.
4	Efficiency	The use of SVeR based on Open Journal System improves time and effort efficiency in the validation process.
		SVeR facilitates users in uploading RPS documents during the validation process.
		SVeR helps users complete the RPS validation process more effectively
7	Usability	The font size used in SVeR is appropriate and easy to read
		The font type used in SVeR is appropriate and easy to understand
		The colour composition used in SVeR is appropriate and comfortable for users.
		The design and background selection of SVeR support user convenience
		The menus and navigation features of SVeR are clear and easy to understand
		The validation format and workflow provided by SVeR are easy to operate.
		The user instructions provided in SVeR are clear and understandable.
		The standardized RPS format and validation guidelines help users perform the validation process.
		The output information generated by SVeR is easy to understand
		The login process in SVeR is easy to perform.
		SVeR facilitates users in entering data and uploading user documents.

The effectiveness questionnaire was administered to lecturers or users who had operated SVeR. The instrument was used to measure the perceived contribution of the system to the effectiveness of the RPS validation process. The questionnaire consisted of seven items grouped into two aspects, namely the effectiveness of system implementation and system utilization.

Table 4. Effectiveness Questionnaire Blueprint

No.	Aspect	Indicator/Statement
1	Process Effectiveness	The e-RPS Validation System helps lecturers obtain certainty regarding the validation status of learning devices.
		The e-RPS Validation System assists lecturers in completing the validation process of learning devices.
2	Content Effectiveness	The e-RPS Validation System improves the quality of RPS documents produced by lecturers.
3	Results Effectiveness	The e-RPS Validation System increases the number of validated RPS documents.

No.	Aspect	Indicator/Statement
4	Feedback Effectiveness	The e-RPS Validation System is beneficial for supporting users' work activities.
		Users are satisfied with utilizing the e-RPS Validation System to facilitate their work.
		Users intend to utilize the e-RPS Validation System regularly in the future.

While the Validity Instrument focuses on expert evaluation of the system's design and functionality, the Practicality Instrument assesses the system's real-world utility, ease of use, and overall benefit from the perspective of those who regularly interact with it. The data that has been collected is then analyzed in 3 ways, namely product validity analysis, product practicality analysis, and product effectiveness analysis. Analysis of the validity of the product that has been developed is carried out by processing data using Aiken's V formula as follows:

$$V = \frac{s}{n(c-1)} \quad (1)$$

Note:
V = Content validity coefficient, which is the rater agreement index regarding the validity of each criterion.
s = The lowest score reduces the score assigned to each rater in the category used, with (s = r –lo, where r is the rater's chosen score, and lo is the lowest score in the scoring category)
n = Number of raters
c = The number of categories that raters can choose from

The results of calculating the content validity coefficient (V) are expressed using the criteria in the following Table 5.

Table 5. Product Validity Criteria

No.	Validity Results (V)	Validity Criteria
1	0.76 – 1.00	Very High
2	0.51 – 0.75	High
3	0.26 – 0.50	Medium
4	0.00 – 0.25	Low

The practicality criteria used in this research are the percentage technique proposed by A. Muri Yusuf. In this technique, the researcher only looked for the percentage of teachers' needs in implementing the Pancasila student profile in elementary schools from each respondent's school origin. The formula used in this analysis technique is as follows.

$$P = \frac{f}{n} x100 \quad (2)$$

Note:
P = Percentage sought
f = Frequency total score
n = Maximum value

The practicality criteria for the product being developed are shown in Table 6 below.

Table 6. Product Practicality Criteria

No.	Percentage (%)	Practicality Criteria
1	81 – 100	Very Practical
2	61 – 80	Practical
3	41 – 60	Quite Practical
4	21 – 40	Less Practical
5	0 – 20	Not Practical

The analysis of system effectiveness data is seen from four dimensions: content, process, results, and feedback. Indicators are determined for each dimension. The data collected is analysed using the moment kappa formula as a reference.

$$Moment\ Kappa\ (k) = \frac{\rho - \rho e}{1 - \rho e} \quad (3)$$

Note:
K = Kappa moment that shows the effectiveness of the product
p = The realised proportion is calculated by dividing the number of values the user gives by the maximum number of values.
pe = The proportion that is not realised is calculated by subtracting the maximum value from the total value given by the validator, divided by the maximum value.

The criteria for calculating effectiveness tests can be seen in Table 7 below.

Table 7. Product Effectiveness Category

No.	Effectiveness Ratio	Achievement Level
1	0.81 – 1.00	Very High
2	0.61 – 0.80	High
3	0.41 – 0.40	Medium
4	0.21 – 0.40	Low
5	0.01 – 0.20	Very Low
6	≤ 0.00	Ineffective

RESULTS AND DISCUSSION

Results

Needs Analysis Stage

An initial needs analysis was conducted to determine user needs and market share related to the open journal system-based e-RPS validation system. The needs analysis was conducted by interviewing several lecturers in the PGMI (Primary Madrasah Teacher Education) study program regarding validation process issues and initial survey descriptions recorded on e-campus, which were tracked through the quality assurance centre account. The results of the number of learning devices uploaded and validated in the even semester 2023/2024 obtained the following statistical data.

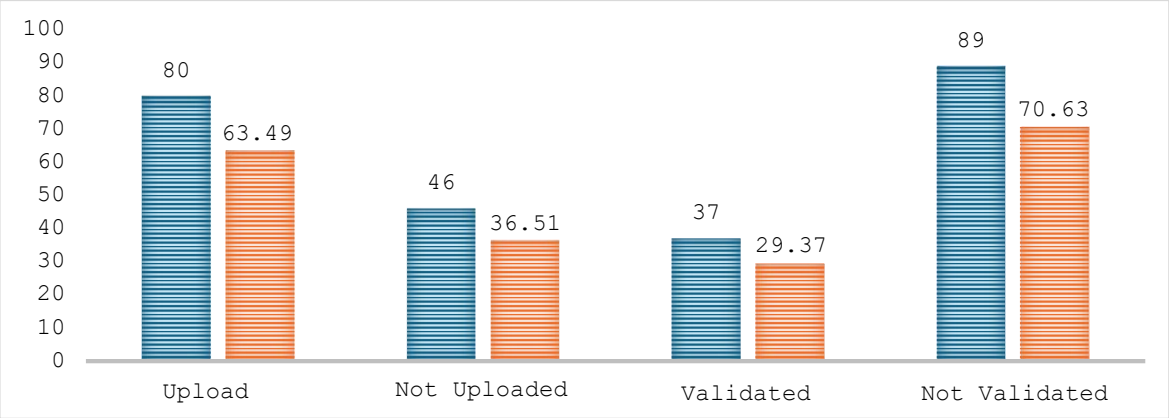

Figure 2. Number of Validated and Unvalidated Learning Devices

Figure 2 shows a graph of the number and percentage of RPS uploaded and validated by lecturers who teach in the elementary school teacher education study program. Based on Graph 2, it can be seen that there are 126 lecturers, 37 of whom have used validated learning tools, while 89 lecturers, or 70.63%, use learning tools that have not been validated. This figure shows that the number of learning tools that are not validated has reached a very high level because more than half of the lecturers do not have measurable/validated learning tools. The finding of many learning tools

that are not validated means that the entire learning process is not following the learning outcomes stated in the study program curriculum.

The high number of learning devices that are not validated indeed has causes that need to be analyzed. Based on the results of interviews conducted by several lecturers who teach in the elementary school teacher education study program, it was stated that the majority had difficulties and did not know the lecturers who would validate the learning tools. This is as per the results of interviews conducted by researchers with WR lecturers, as follows.

"*More precisely, I don't know which lecturer will validate it, so I just upload it and give it to the student." (W1/19 Juli 2024)*

"I don't know who to validate the learning tools with, nor do I know the lecturer." (W2/02 Agustus 2024)

In addition, several other arguments related to the cause of the findings that most lecturers did not validate were because they did not know the validation process and flow that had to be carried out. In contrast, other findings stated they did not have time to go to campus to validate manually. As stated in the interview results by lecturer ES, these findings are as follows.

"*Because I am from Padang City, I only go to campus when teaching; I am confused about where to validate it, with whom, or to the study program; sometimes, I only discuss it with senior lecturers who happen to teach the same course". (W3/04 Agustus 2024).*

Based on the results that have been found, it can be concluded that the ignorance of the personnel who will review and the validation process flow is the main problem of the high number of unvalidated RPS. This means that the RPS validation process requires a unique strategy that can accommodate the difficulties and causes of the issues of unvalidated RPS used by lecturers. The most crucial thing at this time, and one of the needs to accommodate the problems that have been found, is to develop a flexible validation system that can be accessed by all lecturers, saving time, energy, and materials.

System Design Stage

This stage is done by designing the architecture, including sequence and class diagrams, including conceptual data models (CDM) and physical data models (PDM), component design by creating logic flows in pseudocode form, and interface design as a rough description of the system interface. We are designing sequence and class diagrams, including conceptual and physical data models. Some examples of displays from sequence and class diagrams can be seen in Figure 3.

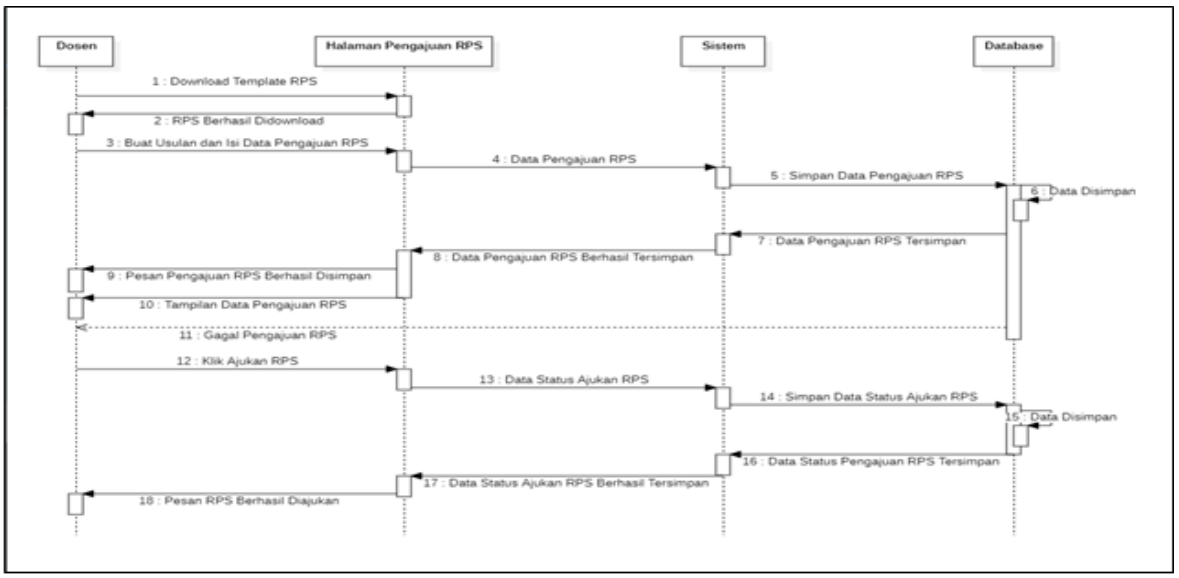

Figure 3. Learning Device Assessment Submission Flow by Lecturers via the System

Based on Figure 3, it can be seen how the flow and process of submitting learning devices to be validated through the SVeR that has been developed. The figure above illustrates the flow of the learning device input process carried out by lecturers, with the flow of lecturers downloading the learning device template and inputting courses, curriculum, study programs, and scientific groups. After this process is completed, the learning device will enter the admin database before being submitted to a reviewer, which is taken based on lecturers who are members of a particular scientific group. The learning device has been input and submitted by the admin. Then, a reviewer is appointed to carry out the validation process and assessment of the learning device that the lecturer has input. In the following process, the reviewer provides an evaluation of the feasibility of the learning device with the assessment notes that have been determined by the system. The following is a sequence diagram of the flow of the device validation process carried out by the Reviewer, as seen in Figure 4.

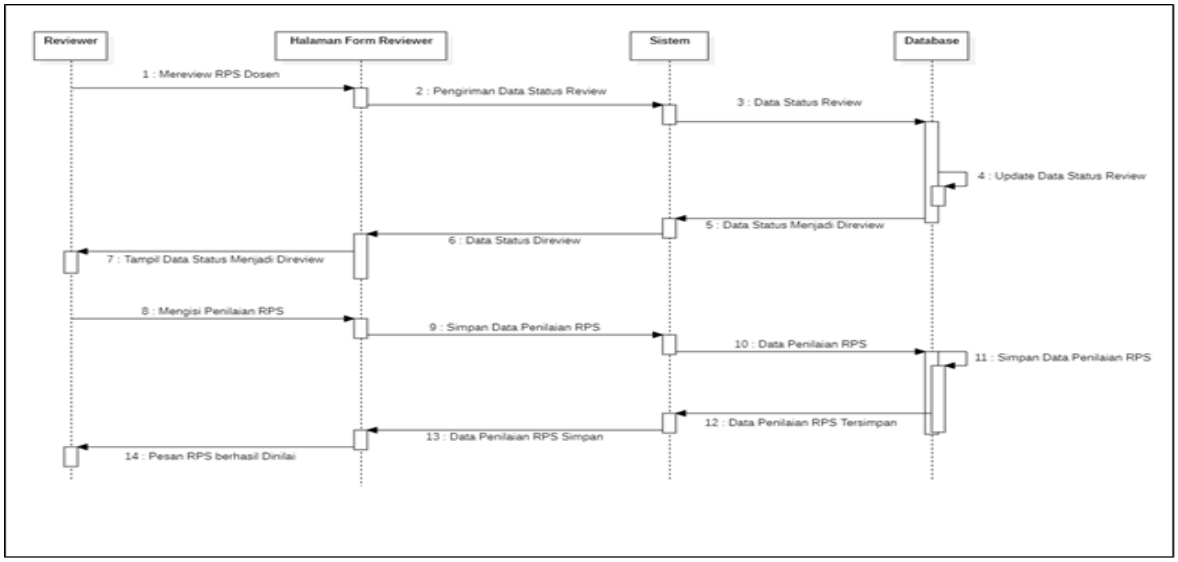

Figure 4. Learning Device Assessment Process Flow by Reviewers via the System

Figure 4 shows the learning device assessment process flow contained in the developed system, SVeR. The reviewer validates after the admin appointments. The system design stage also involves creating a class diagram, as seen in Figure 5 below.

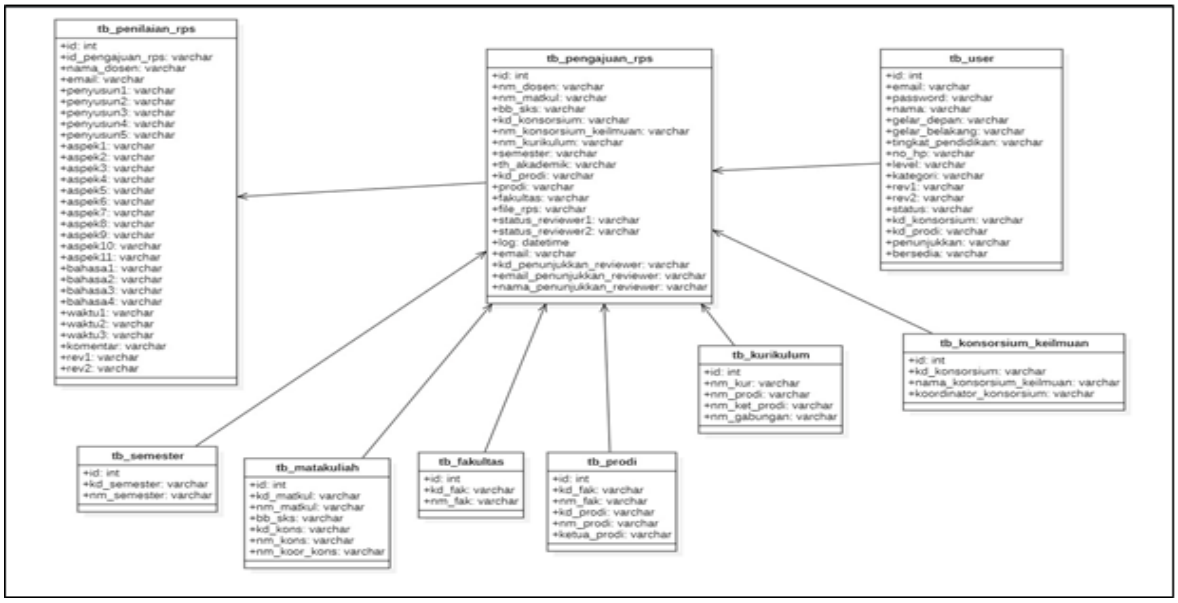

Figure 5. SVeR Class Diagram View

Expert Validation Results

The validity test of the developed product includes three aspects: usability, design, and operation. The validity test data obtained were analyzed using Aiken's V formula. This calculation produces a content validity coefficient, a reference for the developed system's content validity level. In this study, it is known that n = 3 because it involves two media expert validators who are referred to as s1 and two expert validators who are then referred to as s2, while c = 4. After all, the rater can select four categories when scoring: 4 = perfect, 3 = good, 2 = less good, and 1 = not good. As for lo = 1, the lowest score that the rater can select is 1. The recapitulation of the data from calculating the content validity coefficient from the e-RPS validation system based on the open journal system developed using Aiken's V formula is shown in full in Table 8.

Table 8. Results of Student Worksheet Validation by Experts

No.	Aspects	Validator		∑s	n(c-1)	v	Category
		S1	S2				
1	Usability	8	10	18	24	0.750	Very High
2	Design	9	14	23	30	0.767	Very High
3	Operation	18	23	41	45	0.854	Very High
Average						**0.804**	**Very High**

Note: s = the score given by the validator minus the lowest score on the scale (r-lo); n = number of validators; c = number of assessment categories.

Based on the calculation results in Table 8, the validation system based on the open journal system integrated with the developed e-campus has a very high overall validity level, with a final content validity coefficient of 0.804. This figure is obtained from the average of the three aspects assessed in the validity of SVeR: the usability aspect of 0.750, the design aspect of 0.767, and the operational aspect of 0.854.

Product Practicality Test

The practicality or accuracy testing of the validation system (SVeR) based on an open journal system integrated with e-campus developed in this study was conducted by testing it on 16 lecturers who teach at the Elementary School Teacher Education study program, Mahmud Yunus State Islamic University, Batusangkar. The practicality test of the developed e-RPS validation system refers to three aspects of assessment: correctness, efficiency, and usability. The results of the practicality test carried out on the three aspects assessed are obtained in Table 9.

Table 9. Practicality of the SSI-Based Student Worksheet Based on Student Responses

No.	Indicator	Score Acquisition	Max Score	Percentage (%)	Category
1	Correctness	285	300	95	Very Practical
2	Efficiency	353	375	94.13	Very Practical
3	Usability	423	450	94	Very Practical
∑		**1061**	**1125**	**94.31**	**Very Practical**

Based on the calculation results obtained using the percentage formula, the average practicality value of the e-RPS validation system based on an open journal system integrated with e-campus obtained a score of 94.31% with a convenient category. The achievement of the practicality percentage of the developed SVeR has exceeded the target, even entering the range of 81 - 100 with an efficient criterion. This achievement was obtained in detail from the assessment of 3 aspects by users who had conducted the SVeR trial, with more information on the correctness aspect obtaining a percentage of 95%, the efficiency aspect reaching 94.13%, and the usability aspect reaching 94%, where these three aspects are in the efficient category.

Effectiveness of Student Worksheet on Science Concepts

The effectiveness test of the validation system product based on the Open Journal System to test the Feasibility of learning devices includes four assessment criteria: content effectiveness, process effectiveness, result effectiveness, and reciprocal effectiveness. The calculation of the

effectiveness test of the product that has been developed uses the kappa moment formula. The magnitude of the kappa moment represents the level of effectiveness of the system being developed. The analysis for the effectiveness test of the SVeR product is carried out by comparing the four criteria of the developed system product with the validation system that is currently in effect. Table 10 shows the results of calculating the magnitude of the kappa coefficient of the developed SVeR product.

Table 10. Analysis of SVeR Product Effectiveness Test Results

No.	Indicator	ρ-ρ_e	1- ρ_e	(ρ-ρ_e)/1- ρ_e	Category
1	Process Effectiveness	0.882	0.941	0.938	Very High
2	Content Effectiveness	0.906	0.953	0.951	Very High
3	Results Effectiveness	0.843	0.922	0.915	Very High
4	Feedback Effectiveness	0.898	0.949	0.946	Very High
Average		**0.884**	**0.942**	**0.939**	**Very High**

Based on Table 10 above, it can be seen that overall, the assessment of the effectiveness test conducted has an effectiveness level of 0.939 with a very high level of effectiveness. Furthermore, the achievement of the results of the effectiveness test with a very high category from SVeR is also seen in four other indicators, such as process effectiveness with a very high effectiveness category of 0.938, content effectiveness with a value of 0.952 with a very high category, effectiveness of results with an achievement of 0.915 in the very high category, and feedback effectiveness with a value of 0.946 in the very high category.

User Acceptance and System Efficacy

The achievement of a very high level of effectiveness in the product developed, namely SVeR, is believed to be because developing a learning device validation system based on this open journal system is beneficial and facilitates the work of lecturers and reviewers to assess the feasibility of learning devices. To ensure the high effectiveness given by lecturers using SVeR, the researcher took the initiative to add questionnaire items about testimonials and assessments from users about SVeR and its functionality in facilitating the work of lecturers. 15 out of 16 lecturers who filled in the questionnaire gave a rating of 9 on a scale of 1-10 because SVeR helps lecturers facilitate the validation flow of the developed learning devices. Another reason put forward by users about the high effectiveness of SVeR is that this product is very innovative. After all, it facilitates access to semester learning plans, meets reviewers or learning device assessment teams, and saves more time, energy, and materials.

Table 11. User Feedback and Score Ratings for the System for Validation and Evaluation of RPS (SVeR)

No.	Time Stamp	Inisial	Rating	Reason
1	10/6/2024 11:14:25	WR	8	Highly innovative in facilitating lecturers' RPS validation.
2	10/6/2024 11:20:57	DAA	8	Score 8; this greatly simplifies all lecturers' task of validating their RPS.
3	10/6/2024 11:24:40	MAM	8	I give an 8 because it represents how much this application simplifies my work.
4	10/6/2024 11:29:15	IH	10	Outstanding; it significantly simplifies our work.
5	10/6/2024 11:33:02	ES	9	Because the presence of SVeR will assist my job as a lecturer in validating my learning materials.
6	10/6/2024 11:39:25	IN	9	I strongly agree with the implementation of SVeR as it greatly supports our work effectiveness as lecturers, especially for validating learning materials.
7	10/6/2024 11:54:34	RY	9	This development is highly beneficial in assisting the validation process and workflow.
8	10/6/2024 12:04:54	RA	9	Facilitates access for RPS validation.
9	10/6/2024 13:11:34	NP	9	Extremely helpful in simplifying the validation workflow, eliminating the need for manual validation.

No.	Time Stamp	Inisial	Rating	Reason
10	10/6/2024 15:04:42	WF	9	I give a score of 9 for the developed SVeR because it is generally very good and assists lecturers with RPS validation. This is a new, positive innovation that impacts the quality improvement of lecturers' RPS.
11	10/6/2024 19:00:49	ZH	9	This development is very useful and simplifies my work for validating my learning materials.
12	10/6/2024 19:09:34	SWN	8	Because it greatly assists the lecturer's work in validating the RPS, preventing the use of an RPS that is not/not yet suitable for application during lectures.
13	10/6/2024 19:45:55	NL	9	Outstanding, I am very assisted by this application.
14	10/6/2024 20:30:01	RD	8	Score 8, as a symbol of innovation and how it simplifies my process of validating my learning materials.
15	10/6/2024 20:33:53	YL	9	Score 9 because it eases my job as the head of the scientific consortium in validating the RPS of lecturers teaching in PGMI. Hopefully, this developed application will always be updated if easier and more appealing features become available in the future.
16	10/6/2024 21:49:17	EH	9	I give a score of 9 because it greatly assists in ensuring the availability of validated RPS, thereby supporting the acceleration of the learning process on campus.
17	10/7/2024 9:04:49	SM	8	This development is a brilliant idea that facilitates the RPS validation process for me.

Beyond the statistical findings, As Shown the Table 11, the qualitative feedback gathered from the academic staff provided strong corroborating evidence for the System for Validation and Evaluation of RPS (SVeR)'s efficacy and high user acceptance. The system was overwhelmingly perceived as an "outstanding" and "brilliant idea" (Respondent 4, 17), with nearly all respondents assigning high scores (mean ≈8.88). The positive reception centered on two main themes: workflow simplification and enhancement of quality assurance.

Firstly, users consistently highlighted SVeR's ability to streamline academic procedures. Several lecturers noted that the application "greatly simplifies the work" (Respondent 2) and facilitates access for RPS validation (Respondent 8). This efficiency was crucial, as the system successfully "simplif[ied] the validation workflow, eliminating the need for manual validation" (Respondent 9), thereby saving significant time for both faculty and administrative staff. Furthermore, the convenience extended to specialized roles, with one consortium head stating SVeR "eases my job... in validating the RPS" (Respondent 15).

Secondly, the feedback underscored SVeR's role in improving the quality and relevance of learning materials. Respondents perceived SVeR as an "innovative" tool (Respondent 1, 14) that contributes positively to the "quality improvement of lecturers' RPS" (Respondent 10). Crucially, the system was recognized for "assisting in ensuring the availability of validated RPS" (Respondent 16), which directly supports the acceleration and suitability of the learning process by preventing the use of RPS that is "not/not yet suitable for application during lectures" (Respondent 12). Overall, the uniform and high-value qualitative feedback confirms the system's practical benefits, affirming that SVeR successfully meets the functional and efficiency needs of its users.

Discussion

Based on the results of the research at each stage that has been carried out, it was found that the development of an e-RPS validation system based on an open journal system integrated with e-campus was based on user needs related to the procedures, flow, and efficiency of the validation process of learning devices that resulted in several problems, such as the lecturer's ignorance of the validation flow and process, the lecturer who developed the RPS did not know the validator, and various other limitations such as materials, workforce and time. These problems triggered the high number of RPS in the Elementary School Teacher Education Study Program that had not been validated, reaching 70.63% with 89 RPS. The high number of RPS that were not validated certainly

triggered ambiguity in implementing learning that was not aligned with the Graduate Learning Outcomes and Course Learning Outcomes as stated in the curriculum (Ordu, 2021; Romero & Quilumbaquín, 2022; Farhang et al., 2023; Kouser & Majid, 2021). This argument aligns with several previous studies stating that learning devices spearhead educators in mapping and planning and guide achieving the desired learning objectives (Ahmed, 2023; Ovcharuk et al., 2020; Parwata & Sudiatmika, 2020). Uncertainty about the accuracy of learning tools will trigger many things (Nurlaelah et al., 2021; Anggrella et al., 2023; Setiyowati et al., 2023), such as failure to achieve learning objectives and unmeasured achievements due to a mismatch between the topic and the final objective.

The finding of the high number of unvalidated RPS requires a concrete solution to reduce and minimise the number of unvalidated RPS. The results of the search through interviews to analyse the needs of lecturers for the validation process have been implemented. The recommendations and needs of lecturers as developers of learning devices in the form of RPS are for a systematic digitalisation of the validation process of learning devices so that it will reduce many negative impacts that arise. The system digitalisation process is one of the solutions built and developed in this research process. Digitalisation is needed to facilitate matters (Gorenšek & Kohont, 2019; Kraus et al., 2021; Rakovská, 2020; Zaborovskaia et al., 2020) and reduce the negative impacts of the weak manual validation process. This opinion is based on arguments about the advantages of various digital media and systems developed by previous researchers that system development will increase productivity and work efficiency (Bezrukova et al., 2022; Kravchenko et al., 2019; Mentsiev et al., 2020; Todorov & Todorova, 2021). Therefore, it is clear that the e-RPS Validation system based on an open journal system integrated with e-campus is a product development idea that will minimize the impacts of the high number of unvalidated RPS (Dayi & Mtshali, 2026; Susilo et al., 2026).

The development results have produced a new product called the Validation System based on an open journal system integrated with e-campus, which is then abbreviated as SVeR. The overall content validation results of SVeR based on Aiken's V formulation are 0.804, which is a very high category. The results of this study align with the theory put forward by Aiken that the content validity coefficient is calculated based on the research results from a panel of experts of n people on an item in terms of the extent to which the item is measured. This argument is in line with Guilford's opinion that an information system with validity above 0.8 can be feasible as a system that can measure the achievement of its development goals (Diputra et al., 2020; Mohajan, 2017). The results of this study are also in line with several previous studies (Hasmawaty et al., 2020; Tomoliyus & Sunardianta, 2020). The system development validity index is the starting point for achievement and measurability as a benchmark for system feasibility testing by achieving valid criteria (Nurjanah et al., 2023; Widyaningsih et al., 2021). A system is feasible if the final result of measuring the content validity coefficient is in the valid category. This proves that SVeR as a system development product is possible and guarantees the system's performance capability in achieving the formulated research objectives.

The practicality test of SVeR usage has a percentage of achievement results in the convenient category. The convenient category was obtained because the results of the practicality test reached a rate of 94.31%, which was collected based on the average of the three aspects, namely correctness, efficiency, and usability. Achievements in the convenience category indicate that SVeR is a correct, efficient, and easy-to-use system for carrying out the RPS validation process, as tested on 16 users. This refers to the opinion of Vaske et al., (2002), which defines practicality as ease in using a product or teaching material; the higher the level of practicality, the easier a product is to use (user-friendly). This is in line with the opinion that practicality is the level of usability of media or products based on the results of development (Kadir et al., 2019; Maulana et al., 2024; Yang et al., 2021).

Furthermore, the effectiveness test results were measured based on four indicators, namely content effectiveness, process effectiveness, outcome effectiveness, and feedback effectiveness, which also obtained a value in the very high effectiveness category. The high SVeR effectiveness value is supported by the pattern and process of assessing the validation of learning devices that are easy and flexible to be carried out by lecturers anytime and anywhere. The same thing also happens with system accessibility; lecturers can use SVeR without meeting directly with the learning device validator, which takes time, energy, and materials. The results of the SVeR effectiveness test also

found something unique: several lecturers gave testimonials and gave a score of 9 out of 10 because the presence of SVeR not only supports lecturers' performance in terms of testing the feasibility of the learning devices they make but also increases lecturers' productivity in developing devices well and making them quickly accessible. The high effectiveness test results from users about SVeR, as well as good testimonials about ease, flexibility, and productivity, reflect the development of a website-based system and have a flow based on the work system and open journal system procedures that allow all activities to be carried out quickly, both assessment, data archiving, to the publication of learning devices that have been tested and assessed by reviewers. These results strengthen several previous studies on the effectiveness of system development, stating that development products carried out digitally make work easier and increase user work productivity (Kurniawan, 2022; Raković et al., 2022; Sholichah et al., 2023). The same thing was revealed: information technology helps education management obtain accurate, fast, accessible data and information and facilitates distance learning needs (Al-ayed et al., 2019; Renaldo et al., 2022). Therefore, the development of SVeR as a system used to validate learning devices is effectively used by users, as the assessment results that have been given.

The validation system developed has been measured for its validity, practicality, and effectiveness. The success of this development is supported by development procedures adapted to the analysis of user needs. So that you get a product that meets user expectations, in this way, the developed validation system contributes not only to personal needs as users to obtain appropriate learning tools but also to improving the quality of learning, as well as the vision and mission of the institution. Learning tools validated through this system will guide lecturers in carrying out the learning process so that graduates' planned vision, mission, goals, and learning outcomes can be optimal. The most crucial contribution from the development of SVeR is the fulfillment of accreditation assessment points in criterion 6 point 48 regarding the completeness of curriculum documents, including validated learning tools and assessment matrices that are relevant, up-to-date, and coherent. SVeR will assist the performance of study programs in compiling, gathering, and validating learning tools included in the accreditation assessment criteria in criterion 6 point 48, which is the core point of assessing the completeness of curriculum documents when carrying out accreditation. The fulfillment of validated learning tools will produce maximum value for study programs in achieving superior accreditation rankings based on regulations issued by independent educational accreditation institutions.

CONCLUSION

The findings of this study demonstrate that the developed e-RPS Validation System (SVeR), which is based on the Open Journal System and integrated with the e-campus learning environment, is a valid, practical, and effective system for supporting the validation process of learning devices. The expert validation results indicated that SVeR achieved a very high level of content validity, with an average Aiken's V coefficient of 0.804. The practicality evaluation showed that the system was categorized as very practical, with an overall practicality score of 94.31%, consisting of correctness (95%), efficiency (94.13%), and usability (94%). Furthermore, the effectiveness evaluation indicated a very high level of effectiveness, with an average coefficient of 0.939. The effectiveness dimensions included process effectiveness (0.938), content effectiveness (0.951), results effectiveness (0.915), and feedback effectiveness (0.946). These findings confirm that SVeR can improve the process of documenting, validating, and managing learning device validation activities in a more systematic, efficient, and targeted manner.

From a theoretical perspective, this study contributes to the development of digital validation models for educational management by demonstrating how an online journal-based platform can be adapted to support structured learning device validation workflows. Practically, SVeR provides an alternative solution for higher education institutions to improve the management, documentation, and monitoring of learning device validation processes. The system can support lecturers, validators, and academic managers by providing a more transparent validation mechanism compared with conventional manual procedures.

However, this study has several limitations. First, although SVeR has been designed to support integration with the e-campus environment, full implementation has not yet been realized due to the absence of institutional policies and socialization from higher education leaders. Second, the system evaluation was conducted in a single institutional setting with a limited number of participants, which may restrict the generalizability of the findings to other higher education contexts. Third, this study did not include longitudinal evaluation to examine the long-term impact of SVeR on validation completion rates, workflow efficiency, or sustained user adoption. Fourth, the effectiveness assessment relied primarily on user perceptions, which may introduce subjective bias. In addition, the very high effectiveness scores indicate the possibility of a ceiling effect, where respondents tend to provide highly positive evaluations and limit the ability to identify differences in system performance.

Future studies are recommended to conduct multi-institutional trials involving diverse higher education contexts and larger participant groups. Further research should also investigate longitudinal changes in validation completion rates before and after SVeR implementation, compare SVeR with other digital workflows such as learning management system (LMS)-based validation processes, and evaluate its integration with broader academic information systems. Moreover, future development can expand the application of SVeR to other academic validation processes, including examination paper validation, teaching module validation, and other learning-related document management systems.

REFERENCES

Ahmed, A. O. A (2023). Using efficient planning for achieving course learning outcomes in EFL Classes at Taif University. *European Scientific Journal, ESJ*, *19*(29), 21-36. https://doi.org/10.19044/esj.2023.v19n29p21

Al-ayed, S. I., Al-tit, A. A., & Alashjaee, A. (2019). The effect of digital transformation on organizational performance by a mediating role of digital innovation. *Migration Letters*, *20*(7), 380–394. https://doi.org/10.59670/ml.v20i7.4313

Allen, M. J. (2004). *Assessing academic programs in higher education.* Anker Company.

Anggrella, D. P., Izzati, L. R., & Sudrajat, A. K. (2023). Improving the quality of learning through lesson plan preparation workshops for an independent learning model. *Indonesia Journal of Community Service and Empowerment*, *4*(1), 162–171. https://doi.org/10.22219/jcse.v4i1.24581

Apriany, R., & Setiawan, S. (2022). Perancangan sistem informasi pembayaran sekolah berbasis web pada SIT Al Haraki. *Jurnal Keilmuan Teknologi Informasi dan Ilmu Manajemen*, *2*(2), 32–39. http://jurnalilmiah.id/index.php/Justifi/article/view/43

Arikunto, S. (2012). *Fundamentals of educational evaluation*. Rineka Cipta.

Ayriza, Y. (2013). Penyusunan dan validasi modul "social life skill" bagi pendidik anak-anak prasekolah. *Jurnal Penelitian dan Evaluasi Pendidikan*, *12*(2), 213–231. https://doi.org/10.21831/pep.v12i2.1428

Aziira, A. H., Kamil, H., & Kartika, A. D. (2023). Pembangunan sistem informasi pengelolaan rencana pembelajaran semester (RPS). *Jurnal Nasional Teknologi dan Sistem Informasi*, *9*(2), 103–112. https://doi.org/10.25077/teknosi.v9i2.2023.103-112

Bamary, K., Behboudi, M. R., & Abbasnejad, T. (2022). An ICT Performance evaluation model based on meta-synthesis approach. *Journal of Information Systems and Telecommunication*, *10*(3), 229–240. https://doi.org/10.7208/chicago/9780226655895.003.0001

Bezrukova, N., Huk, L., Chmil, H., Verbivska, L., Komchatnykh, O., & Kozlovskyi, Y. (2022). Digitalization as a trend of modern development of the world economy. *WSEAS Transactions on Environment and Development*, *18*(13), 120–129. https://doi.org/10.37394/232015.2022.18.13

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university: What the student does* (4th ed.). McGraw-Hill Education.

Budiastuti, D., & Bandur, A. (2020). *Validitas dan Reliabilitas Penelitian*. Mitra Wacana Media

Darmini, A. A. S. R., & Putra, I. N. Wi. A. P. (2009). Pemanfaatan teknologi informasi dan pengaruhnya pada kinerja individual pada Bank Perkreditan Rakyat di Kabupaten Tabanan. *Jurnal Ilmiah Akuntansi dan Bisnis*, *4*(1), 1–15. file:///D:/PEMANFAATAN_TEKNOLOGI_INFORMASI_DAN_PENGARUHNYA_PA.pdf

Dayi, N., & Mtshali, T. I. (2026). Evaluating the GET electrical technology syllabus for transition into FET specialisations in Gauteng Technical Schools. *Jurnal Inovasi Teknologi Pendidikan*, *13*(1), 70–81. https://doi.org/10.21831/jitp.v13i1.90695

Diputra, K. S., Tristiantari, N. K. D., & Jayanta, I. N. L. (2020). Gerakan literasi digital bagi guru-guru sekolah dasar. *JCES (Journal of Character Education Society)*, *3*(1), 118–128. https://doi.org/10.31764/jces.v3i1.1483

Fajrin, N., Kamelia, L., & Juhana, T. (2016). Instalasi dan implementasi open journal system di local area network laboratorium telematika STEI-ITB. *SENTER*, (pp. 26-27). UIN Sunan Gunung Djati Bandung. https://senter.ee.uinsgd.ac.id/repositori/index.php/prosiding/article/view/senter2016p3

Farhang, A. P. Q., Hashemi, A. P. S. S. A., & Ghorianfar, A. P. S. M. (2023). Lesson plan and its importance in teaching process. *International Journal of Current Science Research and Review*, *06*(08), 5901–5913. https://doi.org/10.47191/ijcsrr/v6-i8-57

Fink, L. D. (2013). *Creating significant learning experiences: An integrated approach to designing college courses* (2nd ed.). Jossey-Bass.

Firdaus, T. A., Putra, R. H., Arifandi, F., Anam, M. K., & Lathifah, L. (2023). Implementasi sistem rencana pembelajaran semester berbasis web untuk mempermudah proses pembelajaran. *Jurnal Teknoinfo*, *17*(1), 156-169. https://doi.org/10.33365/jti.v17i1.2348

Foumani, M. F., & Goudariz, S. M. (2021). The Development of a Hybrid Error Feedback Model for Sales Forecasting. *Journal of Information Systems and Telecommunication*, *9*(34), 131–140. https://doi.org/10.29252/jist.9.34.131

Gorenšek, T., & Kohont, A. (2019). Conceptualization of digitalization: Opportunities and challenges for organizations in the Euro-mediterranean area. *International Journal of Euro-Mediterranean Studies*, *12*(2), 93–115. https://www.dlib.si/details/URN:NBN:SI:DOC-XBGA1JHF?&language=eng

Handayani, I., Febriyanto, E., & Shofwatullah, M. (2019). Peningkatan sistem pengelolaan e-journal berbasis open journal system (OJS) 2.3.4 ke versi 3.1.0.1. *Jurnal Ilmiah SISFOTENIKA*, *9*(1), 1–13. https://doi.org/10.30700/jst.v9i1.422

Hasmawaty, H., Syam, H., & Saman, A. (2020). Validity, practicality, and effectiveness: The last step in development of entrepreneurship education based role-playing for kindergarten. *Universal Journal of Educational Research*, *8*(12B), 8092–8101. https://doi.org/10.13189/ujer.2020.082611

Helmina, H., Santoso, H., Nurdin, N., & Ikhsan, M. (2023). Perancangan sistem evaluasi Dosen oleh Mahasiswa (Edom) Universitas Muhammadiyah Jambi berbasis website. *Jurnal Informatika, Sistem Informasi dan Kehutanan (FORSINTA)*, *2*(1), 14–20. https://doi.org/10.53978/jfsa.v2i1.263

Kadir, J. S., Zaim, M., & Refnaldi, R. (2019). Developing instruments for evaluating validity, practicality, and effectiveness of the authentic assessment for speaking skill at junior high

school. *6th International Conference on English Language and Teaching (ICOELT 2018) Developing*, (276), 98–105. https://doi.org/10.2991/icoelt-18.2019.14

Kalavaini, K. et al. (2021). Predicting student performance for early intervention using classification algorithms in machine learning. *Journal of Information Systems and Telecommunication*, *9*(36), 226–235. https://doi.org/10.52547/JIST.9.36.226

Kouser, S., & Majid, I. (2021). Technological tools for enhancing teaching and learning process. *Towards Excellence*, *13*(1), 366–373. https://doi.org/10.37867/te130133

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. *SAGE Open*, *11*(3). https://doi.org/10.1177/21582440211047576

Kravchenko, O., Leshchenko, M., Marushchak, D., & Vdovychenko, Y. (2019). Digitalization as a global trend and growth factor of the modern economy. *CEUR Workshop Proceedings*, *2422*, 434–443. https://doi.org/10.1051/shsconf/20196507004

Kurniawan, M. S. (2022). The role of information technology in improving the effectiveness of education management. *Journal on Education*, *04*(04), 1658–1665. https://repository.poltekapp.ac.id/id/eprint/3860/

Lialestani, M. M., Khamseh, A., & Radfar, R. (2021). Digital transformation model, based on grounded theory. *Journal of Information Systems and Telecommunication*, *9*(36), 275–284. https://doi.org/10.52547/JIST.9.36.275

Maulana, I., Ganefri, G., & Yulastri, A. (2024). Practicality of using e-learning learning media in entrepreneurship courses. *Journal International of Lingua and Technology*, *3*(1), 163–174. https://doi.org/10.55849/jiltech.v3i1.583

Mentsiev, A. U., Engel, M. V, Tsamaev, A. M., Abubakarov, M. V, & Yushaeva, R. S.-E. (2020). The concept of digitalization and its impact on the modern economy. *Proceedings of the International Scientific Conference "Far East Con" (ISCFEC 2020)*, *128*(March), 10–15. https://doi.org/10.2991/aebmr.k.200312.422

Mohajan, H. K. (2017). Two criteria for good measurements in research: Validity and reliability. *Annals of Spiru Haret University. Economic Series*, *17*(4), 59–82. https://doi.org/10.26458/1746

Muhsinin, U., & Fatmawati, K. (2020). Validitas dan praktikalitas rencana pembelajaran semester (RPS) terintegrasi research based learning. *Jurnal Ilmiah Universitas Batanghari Jambi*, *20*(1), 201-206. https://doi.org/10.33087/jiubj.v20i1.791

Munthe, B. O., Amalia, F., & Cholissodin, I. (2019). Pengembangan sistem informasi penilaian dan evaluasi kinerja karyawan dengan metode weighted product berbasis web. *Pengembangan Teknologi Informasi dan Ilmu Komputer*, *3*(9), 9095–9104. https://j-ptiik.ub.ac.id/plugins/generic/pdfJsViewer/pdf.js/web/viewer.html?file=https%3A%2F%2Fj-ptiik.ub.ac.id%2Findex.php%2Fj-ptiik%2Farticle%2Fdownload%2F6348%2F3055%2F44333

Muslihudin, M., Imamudin, M. A., Mohidin, S.Kom, M.T, I., Musa, S.T., M.Kom, S. B., Badu, F., irfan & soyusiawaty dewi, Zain, S. A., Sari, E. M., & Arif, M. (2019). Pengembangan sistem informasi penerimaan siswa baru berbasis web di SMA 1 Annuqayah Sumenep. *Jurnal Ilmiah Pendidikan dan Informatikan*, *4*(2), 53-62. https://doi.org/10.21107/edutic.v4i2.3914

Nurafni, Tjandi, Y., Mappeasse, M. Y., Suhardi, I., & Riska, M. (2022). Pengembangan sistem informasi pelaporan kinerja guru pada keterlaksanaan pembelajaran berbasis dashboard di SMKN 3 Takalar. *Information Technology Education Journal*, *1*(2), 7–17. https://doi.org/10.59562/intec.v1i2.228

Nurjanah, S., Istiyono, E., Widihastuti, W., Iqbal, M., & Kamal, S. (2023). The application of Aiken's V method for evaluating the content validity of instruments that measure the implementation of formative assessments. *Journal of Research and Educational Research Evaluation*, *12*(2), 2023–2125. https://doi.org/10.15294/jere.v12i2.76451

Nurlaelah, N., Syahid, A., Fuady, M. I. N., & Lestari, M. F. (2021). Improving learning activities and outcomes of students by application of observation-based learning. *Universal Journal of Educational Research*, *9*(3), 479–486. https://doi.org/10.13189/ujer.2021.090307

Ordu, U. B. A (2021). The role of teaching and learning aids/methods in a changing world. *New Challenges to Education: Lessons from Around the World*, *19*, 210–216. https://eric.ed.gov/?id=ED613989

Ovcharuk, O., Ivaniuk, I., Soroko, N., Gritsenchuk, O., & Kravchyna, O. (2020). The use of digital learning tools in the teachers' professional activities to ensure sustainable development and democratization of education in European countries. *E3S Web of Conferences*, *166*, 1-6. https://doi.org/10.1051/e3sconf/202016610019

Parwata, K. Y. L., & Sudiatmika, A. A. I. A. R. (2020). The effectiveness of learning tools in science learning. *Journal of Physics: Conference Series*, *1503*(1), 1-8. https://doi.org/10.1088/1742-6596/1503/1/012049

Prastika, Y. (2022). *Pengembangan pembelajaran e-learning berbasis syam-ok pada mata kuliah manajemen pembelajaran di Progam Studi Teknologi Pendidikan*. [Thesis, Universitas Negeri Makassar. http://eprints.unm.ac.id/24241/%0Ahttp://eprints.unm.ac.id/24241/1/SKRIPSIJILID.pdf

Raković, L., Sakal, M., & Matkovic, P. (2022). Digital workplace: Advantages and challenges Digital workplace – advantages and challenges Дигитално радно место – предности и изазови. *Анали Економског Факултета у Суботици – The Annals of the Faculty of Economics in Subotica*, *58*(47), 65–78. https://doi.org/10.5937/AnEkSub2247065R

Rakovská, J. (2020). The impact of digitization and automation of production on the role of the workforce in companies in Slovakia. *SHS Web of Conferences*, *83*, 1-7. https://doi.org/10.1051/shsconf/20208301055

Renaldo, N., Suhardjo, Suharti, Suyono & Cecilia (2022). Benefits and challenges of technology and information systems on performance. *Journal of Applied Businerss and Technology*, *3*(3), 302–305. https://doi.org/10.35145/jabt.v3i3.114

Romero, M. V. D., & Quilumbaquín, E. C. A. (2022). Herramientas educativas como apoyo en la enseñanza. *Mendive. Revista de Educación*, *20*(4), 1099–1108. https://dialnet.unirioja.es/servlet/articulo?codigo=8730168

Salamun, S., & Arisandi, D. (2020). Sistem monitoring kinerja Dosen pada institusi perguruan tinggi swasta (Studi kasus: Universitas Abdurrab). *Digital Zone: Jurnal Teknologi Informasi dan Komunikasi*, *11*(2), 198–208. https://doi.org/10.31849/digitalzone.v11i2.4304

Saputri, Y. G., & Guspatni, G. (2021). Validitas dan praktikalitas media pembelajaran PowerPoint-iSpring terintegrasi pertanyaan prompting pada materi larutan elektrolit dan nonelektrolit kelas X SMA/MA. *Entalpi Pendidikan Kimia*, *2*(1), 57–65. https://doi.org/10.24036/epk.v2i1.128

Setiawan, R., Kurniadi, D., & Supriatna, Y. (2023). Perancangan sistem informasi monitoring dan pelaporan kinerja aparatur sipil negara berbasis web dan Android. *Jurnal Algoritma*, *20*(1), 156–167. https://doi.org/10.33364/algoritma/v.20-1.1281

Setiyowati, R., Fatihah, H., Handoko, A. I., Chairunnisa, D., & Parianda, P. J. (2023). The urgency of using teaching materials based on e-book problem-based learning. *Proceedings of the Fifth Sriwijaya University Learning and Education International Conference (SULE-IC 2022)*, *1*, 59–64. https://doi.org/10.2991/978-2-38476-010-7_8

Sholichah, A. S., Alam, M., & Sastradiharja, E. E. J. (2023). Digitalization of education and its impact on urban society: A study on junior high school teachers. *Al-Ishlah: Jurnal Pendidikan*, *15*(3), 2895–2905. https://doi.org/10.35445/alishlah.v15i3.2103

Stranack, K. (2006). The role of open source software in scholarly publishing. *First Monday*, *11*(10). https://doi.org/10.5210/fm.v11i10.1402

Susilo, A., Fauziyyah, A., Hartari, A., Nurdiana, D., & Endah, E. Y. (2026). Enhancing student academic services through AI-driven virtual assistants using the RAG method at Universitas Terbuka. *Jurnal Inovasi Teknologi Pendidikan*, *13*(1), 57–69. https://doi.org/10.21831/jitp.v13i1.83632

Todorov, I., & Todorova, N. (2021). Managing sustainability of national security: Implications for Ukraine. *E3S Web of Conferences*, *307*, 1–15. https://doi.org/10.1051/e3sconf/202130709001

Tomoliyus, T., & Sunardianta, R. (2020). Validitas Aiken's instrumen tes untuk mengukur reaktif agility olahraga khusus tenis meja. *Jurnal Keolahragaan*, *8*(2), 148–157. https://doi.org/10.21831/jk.v8i2.32492

Vaske, J. J., Whittaker, D., Shelby, B., & Manfredo, M. J. (2002). Indicators and standards: Developing definitions of quality. In *Wildlife Viewing in North America: A Management Planning Handbook*, (pp. 143–171). Corvallis. https://www.researchgate.net/publication/250613443_Indicators_and_Standards_Developing_Definitions_of_Quality

Widyaningsih, S. W., Yusuf, I., Prasetyo, Z. K., & Istiyono, E. (2021). The development of the hots test of physics based on modern test theory: Question modeling through e-learning of Moodle LMS. *International Journal of Instruction*, *14*(4), 51–68. https://doi.org/10.29333/iji.2021.1444a

Willinsky, J. (2005). Open Journal Systems: An example of open source software for journal management and publishing. *Library Hi Tech*, *23*(4), 504–519. https://doi.org/10.1108/07378830510636300

Yang, Z., Laffréchine, K., Bony-Dandrieux, A., Dolidon, H., & Barroca, B. (2021). Practical indicators for road infrastructure resilience to flood risks in France, case study of Nantes Ring Road network. *FLOODrisk 2020 – 4th European Conference on Flood Risk Management*, 207–213. https://doi.org/10.3311/floodrisk2020.11.21

Zaborovskaia, O., Nadezhina, O., & Avduevskaya, E. (2020). The impact of digitalization on the formation of human capital at the regional level. *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(4), 1–24. https://doi.org/10.3390/joitmc6040184

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (213-228)
Online: http://journal.uny.ac.id/index.php/jitp

Analysis of ChatGPT user acceptance among schools in South Tondano District

Indra Rianto[1] *, Tesalonika Inryanti Tampi[2]
[1] Universitas Negeri Manado, Indonesia.
[2] Universitas Sariputra Indonesia Tomohon, Indonesia.
***** Corresponding Author. E-mail: indrarianto@unima.ac.id

ARTICLE INFO

Article History
Received:
24 June 2025;
Revised:
21 June 2026;
Accepted:
24 June 2026;
Available online:
30 June 2026.

Keywords
Behavioral intention to use; Perceived ease of use; Perceived usefulness

ABSTRACT

This study analyzes the relationships among Perceived Ease of Use (PEOU), Perceived Usefulness (PU), and Behavioral Intention to Use (BI) in the context of educational technology acceptance. The study involved 100 respondents, comprising 80 students and 20 teachers, whose responses were analyzed as a single dataset because both groups evaluated the same technology and research constructs. The proposed model was tested using Partial Least Squares–Structural Equation Modeling (PLS-SEM) to evaluate the measurement model and structural relationships among variables. The measurement model was assessed using factor loadings, the Fornell–Larcker criterion, cross-loadings, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE). The structural model and hypotheses were evaluated using bootstrapping in SmartPLS. The findings show that Perceived Ease of Use has a significant positive effect on both Behavioral Intention to Use and Perceived Usefulness, while Perceived Usefulness does not significantly influence Behavioral Intention to Use. These results indicate that ease of use is the primary factor driving technology acceptance among students and teachers. Overall, improving system usability is more effective in promoting technology acceptance than focusing solely on functional benefits. The findings provide practical implications for developers and educational institutions in designing user-friendly educational technologies that meet the needs of both students and teachers.

How to cite:
Indra, R., & Tampi, T. I. (2026). Analysis of ChatGPT user acceptance among schools in South Tondano District. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 213-228. https://doi.org/10.21831/jitp.v13i2.87595

INTRODUCTION

In the current digital era, the rapid development of artificial intelligence (AI), particularly conversational AI applications such as ChatGPT, has significantly transformed various sectors, including education (Gill et al., 2024; Muktiarso, 2024). Developed by OpenAI, ChatGPT can generate human-like responses, provide explanations, answer questions, and help users complete various academic and professional tasks. These capabilities have made ChatGPT an increasingly popular educational tool, supporting both learning and teaching activities (Amala et al., 2024). Unlike conventional educational technologies, ChatGPT offers interactive and personalized assistance that can be accessed anytime and anywhere, making it beneficial not only for students but also for teachers in preparing instructional materials, designing learning activities, and improving classroom efficiency (Aisyah et al., 2024). Within the Technology Acceptance Model (TAM), Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are recognized as the two

primary factors influencing an individual's intention to adopt new technologies (Wang et al., 2025; Rahmatika & Fajar, 2019). In educational settings, these constructs are relevant for both students and teachers, although they may perceive AI technologies from different perspectives. Students generally utilize ChatGPT to understand course materials, complete assignments, and support independent learning, whereas teachers employ the technology to prepare teaching materials, generate instructional content, and improve the effectiveness of classroom activities. Consequently, understanding technology acceptance requires considering the perspectives of both groups, as they represent the primary users of AI-based educational technologies (Qin et al., 2020).

The increasing adoption of AI in education has become even more prominent following the COVID-19 pandemic, which accelerated the integration of digital technologies into teaching and learning processes (Mhlongo et al., 2023; Lestari & Kurnia, 2023). As educational institutions continue implementing technology-enhanced learning, ChatGPT has emerged as one of the most widely used AI applications due to its ability to provide immediate responses and personalized assistance. For students, ChatGPT facilitates self-directed learning by providing explanations tailored to their level of understanding and helping them solve academic problems more efficiently (Lee et al., 2024; Saputra, 2023). For teachers, the technology reduces the time required to prepare instructional materials, supports lesson planning, and provides alternative approaches for delivering learning content. Previous studies have shown that AI-based technologies improve learning effectiveness, increase engagement, and support educational innovation when they are accepted and appropriately utilized by users (Alimuddin et al., 2023; Jayawardana et al., 2023).

Despite the growing implementation of ChatGPT in education, previous studies have predominantly focused on students' acceptance of educational technologies, while relatively limited attention has been given to examining the combined perspectives of students and teachers within a single technology acceptance model (Dianti et al., 2023; Atin & Lubis, 2017). Since teachers and students interact with the same technology for different educational purposes, understanding their collective perceptions provides a broader perspective on the factors influencing AI adoption in educational environments (Lin & Chen, 2024). Therefore, this study integrates responses from both user groups to investigate how Perceived Ease of Use, Perceived Usefulness, and Behavioral Intention to Use interact in the acceptance of ChatGPT. Academically, this study contributes to extending the application of the Technology Acceptance Model by examining technology acceptance using responses from two important stakeholder groups within education. Practically, the findings are expected to provide valuable insights for educational institutions, teachers, technology developers, and policymakers in designing AI-based educational technologies that are easy to use, useful, and capable of supporting both teaching and learning activities. As suggested by Damayanti & Nuzuli (2023), successful technology implementation requires a comprehensive understanding of users' perceptions and needs. By considering the perspectives of both students and teachers, educational stakeholders can develop more effective strategies to encourage the sustainable adoption of AI technologies in schools.

Accordingly, this study aims to analyze the effect of Perceived Usefulness (PU) on Behavioral Intention to Use (BI), the effect of Perceived Ease of Use (PEOU) on Behavioral Intention to Use (BI), and the effect of Perceived Ease of Use (PEOU) on Perceived Usefulness (PU) in the context of ChatGPT adoption. The study further seeks to provide a comprehensive understanding of technology acceptance among both students and teachers, thereby offering practical recommendations for improving the implementation and utilization of AI technologies in educational settings.

ChatGPT, one of the leading applications in the field of artificial intelligence, offers a text-based interactive platform that simulates human dialogue. This uniqueness makes it extremely useful in educational contexts, where students can easily pose questions and receive answers tailored to their needs. According to Khoir (2024), the implementation of AI-based technology in the education sector not only enhances interactivity but also enables a learning process that is more adapted to individual student needs. This means that ChatGPT does not merely provide information, but also stimulates the development of students' critical thinking skills by encouraging them to explore and consider various perspectives on the subject matter (Gafar, 2024).

Furthermore, the use of ChatGPT in the educational environment holds significant potential to enrich students' learning experiences (Auna & Hamzah, 2024). This tool can be used by students to understand challenging concepts, complete academic tasks, or obtain guidance in exam preparation. Research by Putri & Khasanah (2022) shows that students who leverage AI-based tools like ChatGPT report significant improvements in their comprehension of subject material and engagement in the learning process. With its ability to provide prompt and accurate feedback, ChatGPT can function as a supportive resource for independent learning, not only helping students acquire knowledge but also encouraging them to seek additional information and further exploration.

As an increasing number of students begin to use ChatGPT in their learning processes, it is crucial to conduct further research on how their perceptions of this technology affect their ongoing intention and motivation to use it. Understanding these aspects can provide valuable insights for educators and technology developers, allowing them to create a more effective and supportive learning environment. In this way, an in-depth exploration of the relationship between ChatGPT usage and student learning experiences can help optimize the application of this technology in classrooms, ultimately leading to more innovative and comprehensive teaching approaches.

The Technology Acceptance Model (TAM) is a widely used theoretical framework for analyzing the factors influencing users' acceptance of technology. Developed by Fred Davis in 1989, the model focuses on two primary variables considered to be the main drivers of technology acceptance: Perceived Usefulness (U) and Perceived Ease of Use (PEOU). Perceived Usefulness refers to an individual's belief that using a particular technology will enhance their performance or efficiency in completing specific tasks (Williyanto & Martani, 2023). In the context of education, this implies that students believe tools such as ChatGPT can help them better understand subject material, accelerate the learning process, or even improve academic outcomes.

On the other hand, Perceived Ease of Use describes the degree to which individuals feel comfortable and encounter minimal difficulty when interacting with technology (Dianaris et al., 2022). If students perceive that the technology they use is easy to understand and operate, they are more likely to adopt it in their learning activities (Sayekti & Mardianto, 2019). These two variables interact and contribute directly to Behavioral Intention to Use (BI), which represents an individual's intention to utilize the technology. In other words, if students perceive that ChatGPT is useful and easy to use, they are more likely to integrate it into their study strategies.

In the educational context, TAM provides valuable insights into how students interact with various technologies and how their perceptions of these technologies can influence their intentions to adopt them. Research by Rahmawati & Narsa (2019) indicates that both Perceived Usefulness and Perceived Ease of Use significantly affect students' intention to adopt technology for learning. For instance, students who believe that ChatGPT can enhance their understanding of subject material and expedite the learning process are more inclined to use this tool in their studies. Moreover, students who feel comfortable using ChatGPT tend to recommend it to their peers, which in turn can promote wider adoption among the student population (Auna & Hamzah, 2024).

Beyond understanding the interplay between these two factors, TAM also provides a useful framework for identifying various barriers that students might encounter when trying to adopt new technology. For example, uncertainty or doubt about the effectiveness of a tool may hinder students from embracing it, as they might be concerned that the tool will not deliver the expected results or could even disrupt their learning process. By addressing these elements, educators and technology developers can design better strategies to support technology adoption, such as providing clear information and adequate training to help students feel more confident when using new tools in their learning processes (Amelia, 2023).

Thus, TAM serves not only as an analytical tool but also as a guide for developing strategies that can enhance technology acceptance in educational environments. This is particularly important in today's digital era, where students are confronted with a wide range of tools and technological resources that can enrich their learning experiences. Ensuring that students understand both the benefits and ease of use of technologies like ChatGPT enables educators to create a more inclusive

and effective learning environment, where students not only have access to these tools but are also motivated to use them actively.

Although the use of technology in education offers significant benefits, challenges and barriers remain and must be addressed seriously. One major challenge often encountered is the lack of adequate training for both students and educators in utilizing new technologies (Suryawijaya, 2024). In a book by Frandicta et al., (2023), it is highlighted that without effective and comprehensive training, students may feel confused or lack confidence when attempting to use technological tools like ChatGPT. Such uncertainty can hinder their intention to adopt the technology, as they might not fully understand how it works or the benefits it offers.

In addition to training issues, accessibility remains a crucial factor in the implementation of technology in education (Rachmi et al., 2024). Students who do not have adequate access to hardware or a stable internet connection often feel marginalized and cannot fully leverage the potential of advanced technology (Najjar & Oktasari, 2023). This creates a disparity in learning opportunities, where some students benefit from sophisticated technology while others do not. This situation can widen the gap in educational opportunities and is a challenge that stakeholders in the education sector need to address.

Another significant challenge is the concern over data security and privacy. With the increased use of AI-based applications like ChatGPT, there is growing apprehension about how students' personal data is collected, stored, and used (Zakiyah et al., 2024). Research by Putri (2024) indicates that uncertainties regarding data protection may cause students to hesitate in using new technology, fearing that their personal information could be misused or accessed by unauthorized parties. Therefore, it is essential for educational institutions to provide clear and transparent information regarding privacy policies and data security measures. Institutions must also take steps to ensure that students feel safe and protected when using technology in their learning processes (Cahyanto, 2023).

Open and honest communication about these issues is crucial. By providing comprehensive explanations about how their data will be managed and protected, educational institutions can help build trust among students regarding the technology being used. Furthermore, by offering proper training and improved access to devices and internet connectivity, schools and universities can better prepare students to effectively adopt new technology. This approach can overcome existing challenges and barriers, allowing the full potential of technology in education to be realized and utilized by all students.

METHOD

The research model proposed in this study is depicted in Figure 1 and can be described as follows: Hypothesis 1, Perceived Usefulness (U), has a positive effect on Behavioral Intention to Use (BI). In other words, the higher the students' perception of ChatGPT's usefulness, the stronger their intention to use it. Hypothesis 2: Perceived Ease of Use (PEOU) has a positive effect on Behavioral Intention to Use (BI). This indicates that if students find ChatGPT easy to use, their intention to utilize it increases. Hypothesis 3: Perceived Ease of Use (PEOU) has a positive effect on Perceived Usefulness (U). This implies that the easier students find ChatGPT to use, the more beneficial they consider it.

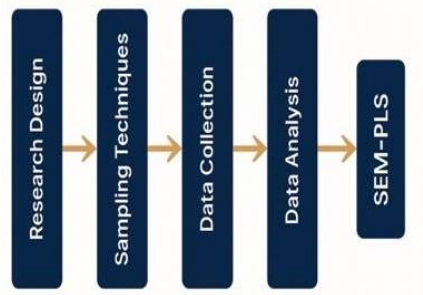

Figure 1. Research Hypothesis Model

A sample refers to a selected subset of the total population that represents the characteristics, attributes, and variability of the population under investigation (Levy & Lemeshow, 2013). By selecting a representative sample, researchers can analyze the collected data and draw conclusions that reflect the broader population. In this study, the sample consisted of 100 respondents, which suggests that the minimum sample size should be at least five times the number of measurement indicators. Since this study employed 20 indicators, a minimum sample of 100 respondents was considered adequate for analysis using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. This study employed a purposive sampling technique. Purposive sampling is a non-probability sampling method in which respondents are selected based on specific criteria established by the researcher to ensure that they are relevant to the objectives of the study. The sample comprised 100 respondents, consisting of 80 students and 20 teachers. Although the respondents represented two different user groups, their responses were integrated into a single dataset because both groups had experience using the same educational technology and evaluated the same research constructs. Therefore, the structural model was estimated using the combined responses of students and teachers. The student respondents were selected based on the following criteria: they had experience using the educational technology or learning system examined in this study, had interacted with the system during learning activities, and voluntarily agreed to participate in the research. Meanwhile, the teacher respondents were selected because they had experience using the same educational technology to support teaching and learning activities, had implemented the system in classroom practice, and voluntarily agreed to participate in the study. By applying these selection criteria, both groups of respondents were considered capable of providing reliable and relevant information regarding the acceptance and use of the educational technology investigated in this research.

The questionnaire distribution will be conducted in November 2024, utilizing both online platforms (e.g., Google Forms) and direct meetings. For online data collection, respondents will complete the questionnaire either directly online or through face-to-face meetings with the researcher. The collected responses will be tabulated by variable, and totals will be computed for each respondent. During the data collection process, the researcher will personally contact prospective respondents to seek their consent to participate in the survey. Those who agree will be sent a link to the questionnaire.

Data analysis begins by evaluating the completeness and appropriateness of the data using descriptive statistics in SPSS, ensuring correct data input, an adequate sample size, and that the data conform to the scale used. Structural Equation Modeling (SEM) is then performed using SmartPLS. The analysis involves tests for convergent validity, discriminant validity, and variable reliability. The structural model is tested using PLS Bootstrapping in SmartPLS, which includes significance testing of path coefficients to evaluate the fit of the empirical model to the theoretical model.

RESULTS AND DISCUSSION

Results

The measurement model test results (factor loading) show the validity of the indicators for each construct in this study. The analysis was conducted using a combined dataset of 100 respondents, consisting of 80 students and 20 teachers. The responses from both groups were analyzed simultaneously because they represented the same research model and measurement constructs. Factor loading values were used to assess the extent to which each indicator reflected its corresponding latent variable. According to Hair et al. (2018), a factor loading value of 0.70 or higher indicates acceptable indicator validity. Behavioral Intention to Use (BI) was initially measured using eight indicators (BI1–BI8). Of these, only three indicators (BI1, BI3, and BI7) met the validity criterion, with factor loadings ranging from 0.889 to 0.911. The remaining indicators (BI2, BI4, BI5, BI6, and BI8) were removed because their factor loading values were below the recommended threshold of 0.70.

Perceived Usefulness (PU) was measured using eight indicators (PE1–PE8). Three indicators (PE2, PE6, and PE8) demonstrated satisfactory validity, with factor loadings ranging from 0.880 to 0.902. Among them, PE2 showed the highest loading (0.902). The remaining indicators (PE1, PE3, PE4, PE5, and PE7) were excluded because they did not meet the minimum factor loading requirement. Perceived Ease of Use (PEOU) was measured using eight indicators (PU1–PU8). Six indicators (PU1, PU2, PU4, PU6, PU7, and PU8) met the validity criterion, with factor loadings ranging from 0.709 to 0.887. PU4 showed the strongest loading (0.887), while PU7 had the lowest acceptable loading (0.709). Indicators PU3 and PU5 were removed due to factor loading values below 0.70. Overall, 24 indicators across the three constructs were evaluated. Twelve indicators met the recommended validity criterion and were retained, while the remaining twelve indicators were excluded because their factor loading values were below 0.70. The retained indicators adequately represent their respective latent constructs and were therefore considered appropriate for subsequent structural model analysis.

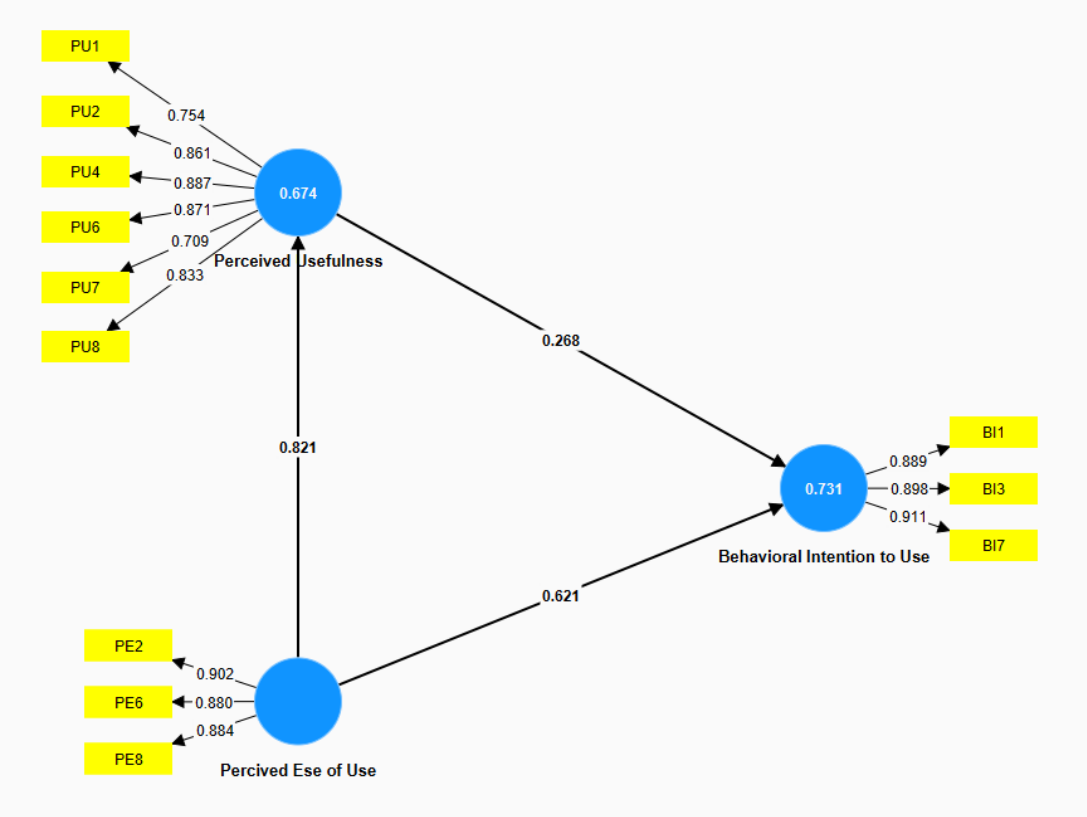

Figure 2. Measurement Model

The Measurement Model Test Result (Factor Loading) Table 1 shows the validity of the indicators for each variable in this study. The factor loading value is used to measure how well the indicator reflects the latent variable. In general, a factor loading value ≥ 0.7 is considered to meet the indicator validity criteria (Hair et al., 2018). Based on the table results, the Behavioral Intention to Use variable is measured using three indicators (BI1, BI3, BI7) with loading values ranging from 0.889 to 0.911, where the BI7 indicator has the highest contribution (0.911). The Perceived Usefulness variable is measured using three indicators (PE2, PE6, PE8), with loading values ranging from 0.880 to 0.902, where the PE2 indicator provides the highest contribution (0.902). The Perceived Ease of Use variable is measured using six indicators (PU1, PU2, PU4, PU6, PU7, PU8) with varying loading values, namely between 0.709 and 0.887. The PU4 indicator has the highest contribution (0.887), while the PU7 indicator shows the lowest contribution (0.709), but still meets the minimum limit of indicator validity.

Overall, all indicators for the tested variables show a factor loading value greater than 0.7, so it can be concluded that these indicators are valid for use in this study. Based on these results, all indicators meet the validity criteria because the factor loading value is greater than 0.7. This shows

that these indicators are statistically able to represent their respective latent variables well. This finding confirms the validity of the measurement and supports the feasibility of the model to proceed to structural testing, such as analysis of relationships between latent variables.

Table 1. Measurement Model Test Result (Factor Loading)

No.	Variables	Indicators	Factor Loading
1	Behavioral Intention to Use	BI1	0.889
		BI3	0.898
		BI7	0.911
2	Perceived Usefulness	PE2	0.902
		PE6	0.880
		PE8	0.884
3	Perceived Ease of Use	PU1	0.754
		PU2	0.861
		PU4	0.887
		PU6	0.871
		PU7	0.709
		PU8	0.833

The discriminant validity test in this study was conducted by considering several criteria, including the Fornell-Larcker Criterion and cross-loading. In the Fornell-Larcker Criterion validity test, the first step is to compare the square root of the Average Variance Extracted (AVE) for each variable with the correlation between variables in the model. Discriminant validity is considered fulfilled if the square root value of AVE is greater than the correlation between different variables. Table 2 presents the results of the Fornell-Larcker Criterion validity test, with the correlation values between variables located outside the diagonal of the table, and the square root of AVE located on the diagonal. Each value on the diagonal indicates the square root of AVE for each variable, which must be greater than the correlation value between other variables located in the corresponding position. Analysis of the table results shows that all variables in the model have a higher AVE square root value compared to the correlation between latent variables. For example, for the Behavioral Intention to Use (BI) variable, the AVE square root value of 0.899 is greater than the correlation with other variables, namely Perceived Effectiveness (PU) (0.778) and Perceived Ease of Use (PEOU) (0.841). Likewise, the Perceived Effectiveness (PU) variable has an AVE square root value of 0.822, which is higher than the correlation between other variables, namely Behavioral Intention to Use (BI) (0.778) and Perceived Ease of Use (PEOU) (0.821). In addition, the Perceived Ease of Use (PEOU) variable has an AVE square root value of 0.889, which is also higher than the correlations with Behavioral Intention to Use (BI) (0.841) and Perceived Usefulness (PU) (0.821).

Overall, the results of the analysis show that each variable in the model has a square root value of AVE greater than the correlation between variables, indicating that discriminant validity has been met. Thus, this model meets the Fornell-Larcker criterion and can be considered valid in terms of discrimination between the variables tested.

Table 2. Fornell-Larcker Criterion

No.	Variables	1	2	3
1	Behavioral Intention to Use	0.899		
2	Perceived Usefulness	0.778	0.822	
3	Perceived Ease of Use	0.841	0.821	0.889

All indicators meet the requirements, considering that their correlation with the intended construct is greater than with other constructs in the model. In addition, the cross-loading value of each indicator is higher against the intended construct compared to other constructs, as shown by the data in Table 3. This indicates that each indicator predominantly measures the intended construct, which reflects good measurement validity.

Table 3. Cross Loading

No.	Indicators	Behavioral Intention to Use	Perceived Usefulness	Perceived Ease of Use
1	BI1	0.889	0.696	0.711
2	BI3	0.898	0.746	0.815
3	BI7	0.911	0.651	0.736
4	PE2	0.715	0.765	0.902
5	PE6	0.782	0.724	0.880
6	PE8	0.744	0.699	0.884
7	PU1	0.428	0.754	0.513
8	PU2	0.722	0.861	0.774
9	PU4	0.711	0.887	0.760
10	PU6	0.745	0.871	0.777
11	PU7	0.393	0.709	0.426
12	PU8	0.698	0.833	0.674

These results indicate that each indicator has the highest loading value on the latent variable that should be measured. For example, indicator BI1 has the highest loading value on the Behavioral Intention to Use variable (0.889) compared to its correlation with other variables such as Perceived Usefulness (0.696) or Perceived Ease of Use (0.711). The same applies to other indicators, such as BI3, which has the highest loading value on Behavioral Intention to Use (0.898), and BI7, which has the highest loading value on Behavioral Intention to Use (0.911). On the Perceived Usefulness variable, indicator PE2 has the highest loading value on this variable (0.765), which is greater than its correlation with other variables, such as Behavioral Intention to Use (0.715) or Perceived Ease of Use (0.902). Likewise, for the PE6 indicator, which has the highest loading value on Perceived Usefulness (0.782), compared to its correlation with other variables such as Behavioral Intention to Use (0.746) or Perceived Ease of Use (0.880). The PE8 indicator also shows the highest loading value on Perceived Usefulness (0.744) compared to its correlation with other variables, such as Behavioral Intention to Use (0.651) and Perceived Ease of Use (0.884). In the Perceived Ease of Use variable, the PU2 indicator has the highest loading value on this variable (0.861), which is higher than its correlation with Behavioral Intention to Use (0.722) or Perceived Usefulness (0.774). Indicators PU4 and PU6 also showed the highest loading values on Perceived Ease of Use with loading values of 0.887 and 0.871, respectively, which were greater than their correlations with other variables such as Behavioral Intention to Use (0.711–0.745) and Perceived Usefulness (0.887–0.777). Overall, these results indicate that the indicators in each variable are more correlated with the corresponding latent variables, indicating good validity in measuring each variable.

The reliability test of the variables in this study was conducted by analyzing the Cronbach's alpha, composite reliability, and Average Variance Extracted (AVE) values. A variable is considered reliable if the Cronbach's alpha value is more than 0.7, the composite reliability is above 0.70, and the AVE reaches a minimum value of 0.50. The results of the reliability and construct validity tests show that all variables in this study have good levels of reliability and validity. In the Behavioral Intention to Use variable, the Cronbach's Alpha value is 0.882, and the rho_A value is 0.885, indicating good internal consistency. The composite reliability for this variable is 0.927, which is greater than the threshold value of 0.70, indicating very good construct reliability. In addition, the AVE value for this variable is 0.809, which is higher than the minimum value of 0.50, indicating good convergent validity. For the Perceived Usefulness variable, the Cronbach's Alpha value is 0.905, and the rho_A value is 0.926, indicating very good internal reliability. The composite reliability value is 0.925, which also indicates high construct reliability. However, the AVE value for this variable is 0.675, which is slightly lower than the threshold of 0.7, although it is still acceptable in some research contexts. Meanwhile, in the Perceived Ease of Use variable, the Cronbach's Alpha value is 0.867 and rho_A is 0.867, indicating good internal reliability. The composite reliability value of 0.918 indicates strong construct reliability. The AVE for this variable is 0.789, which is greater than 0.50, indicating that most of the indicator variance can be explained by the construct.

Overall, the results of the reliability and validity tests of this construct indicate that all variables in this study have good reliability and adequate validity. The variables Behavioral Intention to Use, Perceived Usefulness, and Perceived Ease of Use meet the expected reliability and convergent validity criteria, indicating that the constructs measured in this study can be trusted for use in further analysis. These results indicate that all constructs in this study meet strong reliability and validity criteria, so they can be used for further analysis.

Table 4. Result of the Reliability Testing

No.	Variables	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)	Description
1	Behavioral Intention to Use	0.882	0.885	0.927	0.809	Reliable
2	Perceived Usefulness	0.905	0.926	0.925	0.675	Reliable
3	Perceived Ease of Use	0.867	0.867	0.918	0.789	Reliable

Based on the results shown in Table 4, each indicator shows a value that exceeds the recommended minimum limit. The reliability test of the variables shows that the Cronbach's alpha value for all variables is more than 0.70, the composite reliability is above 0.70, and the AVE exceeds 0.50. Thus, it can be concluded that the reliability of all variables in this study is good.

Table 5. R-Square

No.	Variables	R-square
1	Behavioral Intention to Use	0.731
2	Perceived Usefulness	0.674

The R-square (R^2) analysis can be seen in Table 5, where the Behavioral Intention to Use variable can be explained by 73.1%, indicating a strong influence. This means that most of the variation in Behavioral Intention to Use can be explained by other variables in the model. While Perceived Usefulness can be explained by 67.4%, which also shows a significant influence, although slightly lower. Overall, this R^2 value shows that the model has good predictive power with a strong contribution from the variables in explaining the variation of the two variables.

Table 6. F-Square

No.	Varibles	Behavioral Intention to Use	Perceived Usefulness	Perceived Ease of Use
1	Behavioral Intention to Use			
2	Perceived Usefulness	0.087		
3	Perceived Ease of Use	0.467	2.069	

f^2 (f-square) is a measure used to measure the strength of the influence between two variables in a structural model, such as in PLS-SEM analysis. The f^2 value indicates how much of a change in the dependent variable can be explained by a change in the independent variable. I use a common interpretation for the f^2 value: if the value is less than 0.02, the influence is considered very small; between 0.02 and 0.15, the influence is small; and more than 0.15, the influence is large. Based on the results obtained, the influence between the variables in this study is mostly small. The influence between Behavioral Intention to Use and Perceived Usefulness of 0.087 indicates a very small influence. Meanwhile, the influence between Behavioral Intention to Use and Perceived Ease of Use is 0.467, which indicates a small to moderate influence. The influence between Perceived Usefulness and Perceived Ease of Use is much greater, with an f^2 value of 2.069, which indicates a large influence. Overall, although most of the influences found were small, the relationship between Perceived Usefulness and Perceived Ease of Use showed a significant influence in this model.

After testing the validity and reliability at the measurement model stage and ensuring that all indicators meet the established standards, the next step is to conduct structural model testing. At

this stage, the main objective is to test the validity of each hypothesis in the study. Structural model testing, or hypothesis testing, is done by evaluating the significance of the path coefficients using the PLS Bootstrapping method through SmartPLS statistical software. The results of this structural model testing are presented in Figure 3 and Table 7.

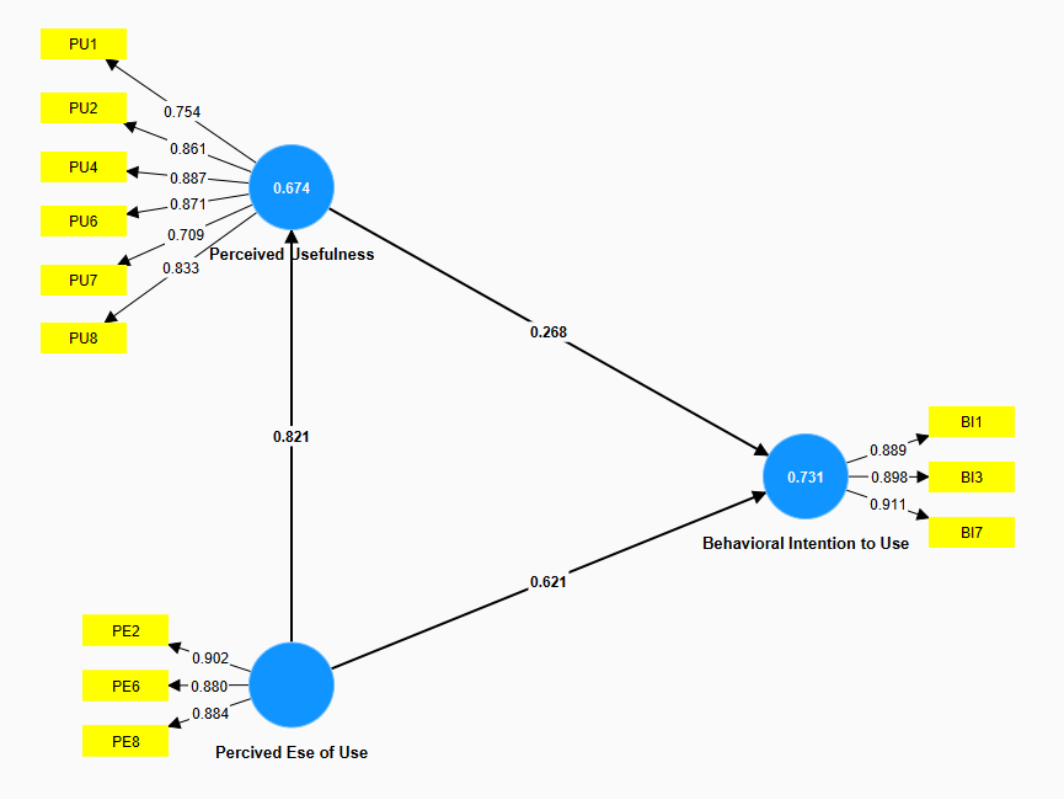

Figure 3. Results of the Structural Models PLS Bootstrapping

Table 7. Results of Hypothesis Testing of Structural Models

Variables	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values	Significant?
Perceived Usefulness -> Behavioral Intention to Use	0.295	0.174	1.542	0.123	No
Perceived Ease of Use -> Behavioral Intention to Use	0.837	0.042	20.049	0.000	Yes
Perceived Ease of Use -> Perceived Usefulness	0.824	0.049	16.751	0.000	Yes

Discussion

This study aims to examine the relationships among Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Behavioral Intention to Use (BI) using the Technology Acceptance Model (TAM). The structural model was analyzed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach with SmartPLS software. The analysis was conducted using a combined dataset of 100 respondents, consisting of 80 students and 20 teachers. Since both respondent groups evaluated the same technology and measurement constructs, their responses were analyzed together in a single structural model. Therefore, the hypothesis testing reflects the overall perceptions of all respondents rather than separate statistical results for students and teachers.

The first hypothesis examined the influence of Perceived Usefulness (PU) on Behavioral Intention to Use (BI). The analysis produced a t-statistic of 1.542 with a p-value of 0.123, which is greater than the significance threshold of 0.05. Therefore, the first hypothesis is not supported, indicating that Perceived Usefulness does not significantly influence Behavioral Intention to Use. Although the Technology Acceptance Model suggests that users are more likely to adopt a technology when they perceive it as useful (Ma & Liu, 2005; Kumala et al., 2020), the findings of this study indicate that perceived usefulness alone is insufficient to increase users' intention to use the system (Alkhawaja, 2022). Considering the characteristics of the respondents, students are generally familiar with digital technologies in their learning activities, while teachers tend to focus on whether the technology effectively supports instructional tasks (Sayaf et al., 2022). When both perspectives are combined, the perceived usefulness of the system may no longer become the primary factor influencing behavioral intention. This finding is consistent with previous studies by Febrian & Ahluwalia (2020) and Sutisna & Sutrisna (2023), which reported that the effect of Perceived Usefulness on Behavioral Intention to Use varies depending on the characteristics of users, technology experience, and the implementation context.

The second hypothesis examined the influence of Perceived Ease of Use (PEOU) on Behavioral Intention to Use (BI). The results show a t-statistic of 20.049 with a p-value of 0.000, indicating a statistically significant positive relationship. Thus, the second hypothesis is accepted. This finding suggests that the easier respondents perceive the technology to be, the stronger their intention to use it. For students, an easy-to-use system enables them to complete learning activities more efficiently without requiring extensive technical knowledge (Zainuddin, 2024). Likewise, teachers are more willing to adopt technology when it can be operated with minimal effort and integrated smoothly into teaching activities (Mehdaoui, 2024). Although the statistical analysis was conducted using a combined dataset, these findings indicate that ease of use is an important consideration for both respondent groups. This result supports the Technology Acceptance Model and is consistent with previous studies conducted by Putri et al., (2021), Putra & Raharjo (2022), and Ashsifa (2020), all of which concluded that Perceived Ease of Use is one of the strongest determinants of technology adoption.

The third hypothesis investigated the influence of Perceived Ease of Use (PEOU) on Perceived Usefulness (PU). The analysis generated a t-statistic of 16.751 with a p-value of 0.000, indicating a significant positive relationship. Therefore, the third hypothesis is supported. The findings imply that respondents perceive technologies that are easier to operate as being more useful in accomplishing their tasks. From the students' perspective, systems that are easy to use simplify learning activities and improve productivity (Silva et al., 2022). From the teachers' perspective, user-friendly technologies facilitate lesson preparation, classroom management, and instructional delivery, thereby increasing the perceived benefits of the system (Álvarez et al., 2024). Although these interpretations describe the possible perspectives of students and teachers, the statistical evidence represents the combined responses of both groups because the structural model was estimated using a single integrated dataset. These findings are consistent with the original Technology Acceptance Model and supported by previous studies by Ardianto et al., (2021), Sutisna & Sutrisna (2023), and Zahara & Amalia (2024), which reported that Perceived Ease of Use significantly enhances Perceived Usefulness.

Overall, the hypothesis testing demonstrates that Perceived Ease of Use is the most influential construct in the proposed model. It has a significant positive effect on both Behavioral Intention to Use and Perceived Usefulness, whereas Perceived Usefulness does not significantly influence Behavioral Intention to Use. These findings indicate that respondents, regardless of whether they are students or teachers, place greater importance on the ease of using the technology than on its perceived functional benefits when deciding whether to adopt it. Consequently, improving system usability is likely to be a more effective strategy for increasing technology acceptance than focusing solely on enhancing its functionality.

CONCLUSION

Based on the results of the structural model testing and hypothesis analysis, this study concludes that Perceived Ease of Use (PEOU) is the most influential factor affecting both Behavioral Intention to Use (BI) and Perceived Usefulness (PU). Conversely, Perceived Usefulness does not have a significant effect on Behavioral Intention to Use, indicating that the perceived benefits of the technology alone are insufficient to encourage users' intention to adopt it. These findings suggest that users are more likely to accept and continue using a technology when it is easy to understand, operate, and integrate into their daily activities. From the students' perspective, the findings imply that technology adoption is primarily driven by ease of use. Students tend to develop stronger intentions to use a learning system when it is intuitive, accessible, and requires minimal effort to operate. Therefore, educational technology developers should prioritize user-friendly interfaces, clear navigation, and simple interaction processes to improve students' learning experiences and encourage continuous system use. From the teachers' perspective, the results indicate that ease of use also plays a critical role in technology adoption. Teachers are more likely to integrate digital technologies into their teaching practices when the systems are easy to learn, require minimal technical support, and can be implemented efficiently in classroom activities. Although the perceived usefulness of the technology remains important, the findings suggest that practical usability is a stronger determinant of teachers' intention to adopt educational technologies. Consequently, training programs and system development should emphasize simplicity, accessibility, and operational efficiency to support technology acceptance among teachers.

REFERENCES

Aisyah, S., Sholeh, M., Lestari, I. B., Yanti, L. D., Nuraini, N., Mayangsari, P., & Mukti, R. A. (2024). Peran penggunaan teknologi dalam pembelajaran IPS di era digital. *Jurnal Inovasi, Evaluasi dan Pengembangan Pembelajaran (JIEPP)*, *4*(1), 44-52. https://doi.org/10.54371/jiepp.v4i1.382

Alimuddin, A., Juntak, J. N. S., Jusnita, R. A. E., Murniawaty, I., & Wono, H. Y. (2023). Teknologi dalam pendidikan: Membantu siswa beradaptasi dengan revolusi industri 4.0. *Journal on Education*, *5*(4), 11777-11790. https://jonedu.org/index.php/joe/article/view/2135

Alkhawaja, M. I., Halim, M. S. A., Abumandil, M. S., & Al-Adwan, A. S. (2022). System quality and student's acceptance of the e-learning system: The serial mediation of perceived usefulness and intention to use. *Contemporary Educational Technology*, *14*(2), 1-15. https://doi.org/10.30935/cedtech/11525

Álvarez, I. M., Manero, B., Romero-Hernández, A., Cárdenas, M., & Masó, I. (2024). Virtual reality platform for teacher training on classroom climate management: Evaluating user acceptance. *Virtual Reality*, *28*(78), 1-17. https://doi.org/10.1007/s10055-024-00973-6

'Amala, Y., Thohir, M., Reditiya, V. E., & Sari, N. I. P. (2023). Refleksi mahasiswa dalam berkeadaban digital melalui ChatGPT. *Intelektual: Jurnal Pendidikan dan Studi Keislaman*, *13*(2), 109-128. https://doi.org/10.33367/ji.v13i2.3978

Amelia, U. (2023). Tantangan pembelajaran era society 5.0 dalam perspektif manajemen pendidikan. *Al-Marsus: Jurnal Manajemen Pendidikan Islam*, *1*(1), 68-82. https://doi.org/10.30983/al-marsus.v1i1.6415

Ardianto, K., Azizah, N., Risiko, P., & Kegunaan, P. (2021). Analisis minat penggunaan dompet digital dengan pendekatan technology acceptance model (TAM) pada pengguna di Kota Surabaya. *Jurnal Pengembangan Wiraswasta*, *23*(1), 13-26. https://doi.org/10.33370/jpw.v23i1.511

Ashsifa, I. (2020). Pengaruh technology acceptance model (TAM) terhadap kepuasan pelanggan dan niat penggunaan mobile banking secara berkelanjutan (privasi dan personalisasi sebagai variabel moderasi). *TECHNOBIZ: International Journal of Business*, *3*(1), 25-29. https://doi.org/10.33365/tb.v3i1.644

Atin, S., & Lubis, R. (2017). Analisis perilaku pengguna pada website sistem informasi akademik universitas XYZ dengan menggunakan technology acceptance model (TAM). *Semnasteknomedia Online*, *5*(1), 1-2. http://ojs.amikom.ac.id/index.php/semnasteknomedia/article/view/1616/1607

Auna, H. S. A., & Hamzah, N. (2024). Studi perspektif siswa terhadap efektivitas pembelajaran matematika dengan penerapan ChatGPT. *HINEF: Jurnal Rumpun Ilmu Pendidikan*, *3*(1), 13-25. https://doi.org/10.37792/hinef.v3i1.1160

Cahyanto, I. (2023). Privacy challenges in using wearable technology in education literature review. *Formosa Journal of Applied Sciences*, *2*(6), 909-928. https://doi.org/10.55927/fjas.v2i6.4272

Damayanti, D., & Nuzuli, A. K. (2023). Evaluasi efektivitas penggunaan teknologi komunikasi dalam pengajaran metode pendidikan tradisional di sekolah dasar. *Journal of Scientech Research and Development*, *5*(1), 208-219. https://doi.org/10.56670/jsrd.v5i1.130

Dianaris, A. A., Pramana, E., & Budianto, H. (2022). Faktor-faktor yang mempengaruhi adopsi e-learning untuk siswa SMA di Indonesia dengan menggunakan extended technology acceptance model. *Journal of Information System, Graphics, Hospitality and Technology*, *4*(01), 13-26. https://doi.org/10.37823/insight.v4i01.179

Dianti, M. R., Zulstra, J. D., & Rahim, H. (2023). Analisis faktor–faktor yang mempengaruhi minat penggunaan uang elektronik (LinkAja). *Jurnal Ekobistek*, *12*(3), 706-711. https://doi.org/10.35134/ekobistek.v12i3.616

Febrian, A., & Ahluwalia, L. (2020). Analisis pengaruh ekuitas merek pada kepuasan dan keterlibatan pelanggan yang berimplikasi pada niat pembelian di e-commerce. *Journal of Theory and Applied Management*, *13*(3), 254-273. https://doi.org/10.20473/jmtt.v13i3.19967

Frandicta, B. B. B. K, Handoyo, G. A. S., Gerald, C. J., Gulo, Y. R. W., Wijaya, A. C. R., Ong, M. P., & Ningsih, D. E. (2023) *ChatGPT dalam pendidikan*. SIEGA Publisher.

Gafar, M. F. (2024). *Jembatan ilmu: AI dalam konteks akademis untuk masa depan pendidikan*. CV Brimedia Global.

Gill, S. S., Xu, M., Patros, P., Wu, H., Kaur, R., Kaur, K., Fuller, S., Singh, M., Arora, P., Parlikad, A. K., Stankovski, V., Abraham, A., Ghosh, S. K., Lutfiyya, A., Kanhere, S. S., Bahsoon, R., Rana, O., Dustdar, S., Sakellariou, R., Uhlig, S., & Buyya, R. (2024). Transformative effects of ChatGPT on modern education: Emerging Era of AI Chatbots. *Internet of Things and Cyber-Physical Systems*, *4*, 19-23. https://doi.org/10.1016/j.iotcps.2023.06.002

Jayawardana, H. B. A., Sugiarto, M. A., & Prystiananta, N. C. (2023). Potensi penerapan pembelajaran berbasis AI (artificial intelligence) di PAUD. *JECIE (Journal Of Early Childhood And Inclusive Education)*, *7*(1), 251-255. https://doi.org/10.31537/jecie.v7i1.1515

Khoir, Q. (2024). Smart classrooms: Mengintegrasikan IoT dan AI untuk pembelajaran yang lebih interaktif dan terukur. *Andragogi: Jurnal Pendidikan dan Pembelajaran*, *4*(1), 1-10. https://doi.org/10.31538/adrg.v4i1.1301

Kumala, D. C., Pranata, J. W., & Thio, S. (2020). Pengaruh perceived usefulness, perceived ease of use, trust, dan security terhadap minat penggunaan Gopay pada generasi X di

Surabaya. *Jurnal Manajemen Perhotelan*, *6*(1), 19-29. https://doi.org/10.9744/jmp.6.1.19-29

Lee, H. Y., Chen, P. H., Wang, W. S., Huang, Y. M., & Wu, T. T. (2024). Empowering ChatGPT with guidance mechanism in blended learning: Effect of self-regulated learning, higher-order thinking skills, and knowledge construction. *International Journal of Educational Technology in Higher Education*, *21*(16), 1-28. https://doi.org/10.1186/s41239-024-00447-4

Lestari, D. I., & Kurnia, H. (2023). Implementasi model pembelajaran inovatif untuk meningkatkan kompetensi profesional guru di era digital. *JPG: Jurnal Pendidikan Guru*, *4*(3), 205-222. https://doi.org/10.32832/jpg.v4i3.14252

Levy, P. S., & Lemeshow, S. (2013). *Sampling of populations: Methods and applications*. John Wiley & Sons.

Lin, H., & Chen, Q. (2024). Artificial intelligence (AI)-integrated educational applications and college students' creativity and academic emotions: students and teachers' perceptions and attitudes. *BMC psychology*, *12*(487), 1-16. https://doi.org/10.1186/s40359-024-01979-0

Ma, Q., & Liu, L. (2005). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing (JOEUC)*, *4*, 112-128. https://doi.org/10.4018/978-1-59140-474-3.ch006

Mehdaoui, A. (2024). Unveiling barriers and challenges of AI technology integration in education: Assessing teachers' perceptions, readiness and anticipated resistance. *Futurity Education*, *4*(4), 95-108. https://doi.org/10.57125/FED.2024.12.25.06

Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. *Heliyon*, *9*(6), 1-20. https://doi.org/10.1016/j.heliyon.2023.e16348

Muktiarso, A. D. (2024). *Adopsi dan implementasi kecerdasan buatan (ChatGPT & Canva AI) sebagai tools public relations di Humas LLDIKTI Wilayah VI*. [Thesis, Universitas Islam Sultan Agung Semarang]. https://repository.unissula.ac.id/35178/

Najjar, S., & Oktasari, H. (2023). Embracing mobile learning in education: Membuka keuntungan, menghadapi tantangan, dan menjelajahi prospek masa depan. *Prosiding Seminar Nasional Kemahasiswaan*, *1*(1), 74-83. https://doi.org/10.56983/prosidingkemahasiswaan.v1i1.1458

Putra, D. N. G., & Raharjo, S. T. (2022). Analisis pengaruh kemudahan penggunaan, kualitas layanan, dan persepsi manfaat terhadap loyalitas pengguna dengan kepuasan pengguna sebagai variabel intervening (studi pada pengguna aplikasi Grab di Kota Semarang). *Diponegoro Journal of Management*, *11*(1), 1-15. https://ejournal3.undip.ac.id/index.php/djom/article/view/33816/26835

Putri, C. A., Yahya, E. S., & Kania, R. (2021). Sikap dan niat perilaku generasi milenial dalam adopsi platform telemedicine untuk layanan konsultasi kesehatan mental. *Prosiding Industrial Research Workshop and National Seminar*, *12*(1), 1073-1080. file:///D:/pirwns,+1073-1080_EBS_22100074_CR_OK-dikonversi%20(2).pdf

Putri, E. O. W. (2024). *Transformasi kontrak dalam era digital: Tantangan hukum bisnis Dalam transaksi elektronik di bisnis sewa kebaya online*. [Thesis Master, Universitas Islam Sultan Agung Semarang]. Repository Unissula. https://repository.unissula.ac.id/id/eprint/35453

Putri, V. V., & Khasanah, I. (2022). Perspektif mahasiswa pendidikan matematika UNISMA 2023 terhadap penggunaan artificial intelligence Chat GPT dalam penyusunan seminar proposal. *J-PRIMA (Jurnal Pembelajaran, Riset, dan Inovasi Matematika)*, *1*(1), 23-35. https://scholar.google.com/scholar?cluster=11684324814399067972&hl=en&oi=scholarr

Qin, F., Li, K., & Yan, J. (2020). Understanding user trust in artificial intelligence-based educational systems: Evidence from China. *British Journal of Educational Technology*, *51*(5), 1693-1710. https://doi.org/10.1111/bjet.12994

Rachmi, Surachman, A., Putri, D. E., Nugroho, A., & Salfin. (2024). Transformasi pendidikan di era digital tantangan dan peluang. *Journal of International Multidisciplinary Research*, *2*(2), 52-63. https://doi.org/10.62504/6y4qb169

Rahmatika, U., & Fajar, M. A. (2019). Faktor-faktor yang mempengaruhi minat penggunaan electronic money: Integrasi model TAM–TPB dengan perceived risk. *Nominal Barometer Riset Akuntansi dan Manajemen*, *8*(2), 274-284. https://doi.org/10.21831/nominal.v8i2.26557

Rahmawati, R. N., & Narsa, I. M. (2019). Penggunaan e-learning dengan technology acceptance model (TAM). *Jurnal Inovasi Teknologi Pendidikan*, *6*(2), 127-136. https://doi.org/10.21831/jitp.v6i2.26232

Saputra, A. B. (2023). *Peran AI dalam dunia pendidikan*. CV Brimedia Global.

Sayaf, A. M., Alamri, M. M., Alqahtani, M. A., & Alrahmi, W. M. (2022). Factors influencing university students' adoption of digital learning technology in teaching and learning. *Sustainability*, *14*(493), 1-18. https://doi.org/10.3390/su14010493

Sayekti, R., & Mardianto, M. (2019). *Perpustakaan digital: Mengukur penerimaan inovasi teknologi)*. Perdana Publishing.

Silva, K., Induwara, R., Wimukthi, M., Poornika, S., Arachchillage, U. S. S. S., & Jayalath, T. (2022). E-tutor: Comprehensive student productivity management system for education. *2022 4th International conference on advancements in computing (ICAC)*, (pp. 108-113). IEEE. https://doi.org/10.1109/ICAC57685.2022.10025237

Sulianta, F. (2024). *Langkah instan belajar literasi digital untuk berbagai kalangan*. Feri Sulianta.

Suryawijaya, T. W. E. (2023). Memperkuat keamanan data melalui teknologi blockchain: Mengeksplorasi implementasi sukses dalam transformasi digital di Indonesia. *Jurnal Studi Kebijakan Publik*, *2*(1), 55-68. https://doi.org/10.21787/jskp.2.2023.55-68

Sutisna, N., & Sutrisna (2023). Implementasikan sistem informasi dalam mendukung perilaku pembelian terhadap keputusan pembelian e-commerce. *Jurnal MENTARI: Manajemen, Pendidikan dan Teknologi Informasi*, *2*(1), 20-30. https://doi.org/10.33050/mentari.v2i1.343

Wang, Z., Wang, Y., Zeng, Y., Su, J., & Li, Z. (2025). An investigation into the acceptance of intelligent care systems: an extended technology acceptance model (TAM). *Scientific Reports*, *15*(17912), 1-20. https://doi.org/10.1038/s41598-025-02746-w

Williyanto, W., & Martani, D. M. (2023). Implementasi sakti dengan pendekatan technology acceptance model. *Coopetition: Jurnal Ilmiah Manajemen*, *14*(3), 555-570. https://doi.org/10.32670/coopetition.v14i3.3364

Zahara, I., & Amalia, N. (2024). Minat Penggunaan aplikasi akuntansi menggunakan TRA dan TAM pada Pusat Kegiatan Belajar Masyarakat (PKBM) di Kabupaten Lampung Selatan. *Jurnal Akuntansi Bisnis Pelita Bangsa*, *9*(01), 77-92. https://doi.org/10.37366/akubis.v9i01.1703

Zainuddin, Z. (2024). Integrating ease of use and affordable gamification-based instruction into a remote learning environment. *Asia Pacific Education Review*, *25*, 1261-1272. https://doi.org/10.1007/s12564-023-09832-6

Zakiyah, N. U., Ameera, V., Ritonga, A. E., Aisah, N., Lingga, S. A., & Akmalia, R. (2024). Penggunaan AI dalam dunia pendidikan. *Mahira: Journal of Arabic Studies*, *4*(1), 1-16. https://doi.org/10.55380/mahira.v4i1.797

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (229-242)
Online: http://journal.uny.ac.id/index.php/jitp

Development of a website-based biology learning resource on environmental change for 10th-grade students

Saprudin*, Noviani, Mahbengi Niate, Sarah Rapma Kristina Sitanggang
Universitas Negeri Yogyakarta, Indonesia.
***** Corresponding Author. E-mail: saprudin.2022@student.uny.ac.id

ARTICLE INFO

Article History
Received:
10 Februari 2026;
Revised:
14 June 2026;
Accepted:
15 June 2026;
Available online:
30 June 2026.

Keywords
Environmental change; Learning media technology; Website

ABSTRACT

This study aims to develop a web-based biology learning resource on environmental change for 10th-grade high school students and determine its feasibility, practicality, and classroom implementability. The development addressed limitations of existing learning media in visualizing abstract and contextual environmental change concepts. The resource was developed using the Research and Development method based on the ADDIE model, consisting of analysis, design, development, implementation, and evaluation. Designed using Google Sites and Canva, the resource integrates content, images, videos, learning objectives, and assessments aligned with learning needs and the Merdeka Curriculum. A limited pilot test involved 18 10th-grade students at South Konawe State High School 10. Evaluation included validation by subject matter and media experts, assessments by biology teachers, and student feedback through questionnaires. Data were analyzed using quantitative descriptive methods. Results showed average validation scores of 4.00 from subject matter experts ("very good"), 3.18 from media experts ("good"), 3.05 from biology teachers ("good"), and 3.23 from students ("good"). Learning implementation reached 91% in the first session and 100% in the second. Limited device access and compatibility were obstacles, overcome through shared or parental devices. Thus, the resource is suitable and practical as supplementary learning material, although accessibility depends on device conditions. Further research should involve larger samples and examine learning outcomes.

How to cite:
Saprudin et al., (2026). Development of a website-based biology learning resource on environmental change for 10th-grade students. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 229-242. https://doi.org/10.21831/jitp.v13i2.95804

INTRODUCTION

The progression of digital technology has transformed human experience into every aspect of existence, notably in education and learning. The role of technology in learning is significant within the processes of teaching and acquiring knowledge (Akram et al., 2022; Said, 2023). Developments in the domain of information and communication technology (ICT) have occurred swiftly and have facilitated numerous human endeavors. The application of ICT enables individuals to transcend constraints of both time and location, particularly in education, where technology is crucial (Wahyuni & Sudarma, 2018). In line with the research by Zou et al., (2025), which states that digital learning, characterized by the integration of information and communication technology (ICT) into educational practices, has become a cornerstone of modern education.

The evolution of learning technology is guided by four primary traits, which include: (1) employing a systematic approach; (2) leveraging a wide range of educational resources; (3) striving to enhance the quality of human learning; and (4) focusing on personalized instructional methods (Warsita, 2017). In the age of digitalization, technology has become integral to education due to its significant impact on knowledge, as students learn about natural occurrences and facts, leveraging technology to apply this information (Maritsa et al., 2021). In the current digital age, the study of biology can be effectively conducted by making use of technological innovations and the internet.

Science, particularly biology, makes a significant contribution to technological development, serving as the foundational science underpinning such advancements (Sudarisman, 2015). In today's digital age, the use of digital devices and the internet is a primary necessity that must be met in the world of education; consequently, teachers are required to innovate in delivering instruction, particularly in biology, by leveraging digital platforms and the internet to embrace the Fourth Industrial Revolution (Jayawardana & Gita, 2020).

Technological advances in today's digital age demand changes in teaching methods to keep pace with developments in the Industry 4.0 era. This is in line with research by Efendi et al., (2026), who state that the rapid development of Industry 4.0 is driving positive transformation in the sustainability of technology-based learning, enabling students to learn and utilize technology. Students at South Konawe State High School 10 are also experiencing this, as they still rely on teaching aids that are ineffective in explaining biological concepts, particularly those related to environmental change. The learning medium currently used is PowerPoint, which makes it difficult for students to understand the material covered in class. Therefore, technology-based learning media are needed to explain material on environmental change, so that students can better understand the subject. Understanding of environmental issues or changes is expected to shape students' character so that they become caring and capable of preserving the environment (Nurwendah et al., 2023). Integrated learning via the internet can help teachers deliver instructional content (Ferdiansyah & Irfan, 2021).

The website served as a digital resource for biology education in the 4.0 era, enabling teachers to use it to facilitate the teaching and learning process. The use of web-based learning tools can provide students with new experiences in their education, thereby enabling a more diverse, engaging, and innovative learning process that improves student achievement (Soussi, 2020; Salsabila & Aslam, 2022). In line with the research by Yanto et al., (2023), web-based teaching media have been proven to be valid, practical, and effective when applied to support learning, as well as efficient in improving the quality of student learning outcomes.

Online education has experienced rapid growth in recent years, leveraging web technology to facilitate the learning experience (Kuswanto, 2018). In line with Najjar et al., (2025), online learning utilizes digital platforms and the internet to facilitate students' access to learning. In the world of education, websites play a vital role in learning by providing information, facilitating communication, fostering creativity, and delivering instructional content (Dinc, 2017). Websites represent a creative advancement that greatly influences the transformation of the educational experience (Nanda & Agustini, 2023). Often referred to as online education or e-learning, web-based learning encompasses course materials accessible via the internet (Purba et al., 2020). In addition, websites can be described as audiovisual learning tools capable of presenting images, audio, video, and learning materials, thereby supporting more effective learning interactions (Yuda et al., 2019). The use of these various components can facilitate students' understanding of biological concepts, particularly those related to environmental change, while also encouraging active participation and independent learning.

The website-based learning media was developed using Google Sites to integrate attractive and accessible text, images, videos, and learning materials. Based on the Cognitive Theory of Multimedia Learning, particularly the signaling and coherence principles, these multimedia components were selected to focus students' attention on essential information and facilitate understanding of abstract biological concepts (Mayer, 2024). Google Sites is a Google product introduced as a website-building tool; users can take advantage of Google Sites because it is easy to create and manage, making it accessible even to inexperienced individuals (Hidayat et al., 2023; Laili et al., 2025; Saputra et al., 2022). Web-based learning tools are highly beneficial in this digital

age for both students and teachers, including: 1) helping students delve deeper into and explore lessons; 2) enabling students to learn independently without relying on others or being tied to a specific location; 3) supporting teachers in implementing interactive teaching methods; and 4) contributing to the improvement of teaching quality in schools (Tambunan & Siagian, 2022).

The use of online platforms as educational tools is likely to be more appropriate for individuals from Generation Z when compared to traditional media like textbooks and other resources (Irnawati & Rahmawan, 2024; Zulaiha et al., 2025). Utilizing websites for educational purposes comes with numerous benefits, including: 1) the ability for students to engage in independent study to enhance and broaden their understanding, 2) increased participation in learning activities, as students not only listen to their instructor's explanation but also partake in various tasks like observing and experimenting, and 3) internet-based educational tools offer supplementary learning materials that can further enrich the content being studied (Setyadi & Qohar, 2017).

Based on the above discussion, research on web-based learning media has demonstrated its potential to support interactive and flexible learning and to enable students to learn independently. However, much of the previous research reviewed in this study still focuses on the development of web-based media in general; therefore, there is a need for media specifically tailored to the characteristics of environmental change content and the learning needs of high school biology students. Therefore, this study developed web-based biology learning media for 10th-grade environmental change material by integrating learning content, videos, user guides, learning objectives, assessments, and reference sources into a single digital platform. The novelty of this study lies in the integration of these various components into Google Sites-based media, which was systematically developed using the ADDIE model while taking into account the needs of teachers, students, the curriculum, and the characteristics of the environmental change material. This study contributes to providing an alternative digital learning resource that can support flexible and self-directed biology learning, while also providing empirical evidence regarding the feasibility, practicality, and implementability of the developed media. Based on this, this study aims to develop web-based learning media on environmental change for 10th-grade high school students so that students can better understand the subject matter and concepts related to environmental change.

METHOD

The research method utilized in this investigation is research and development. The creation of this website involved performing a needs assessment and examining existing studies. Implemented the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) to create educational materials (Fitrianingsih et al., 2023).

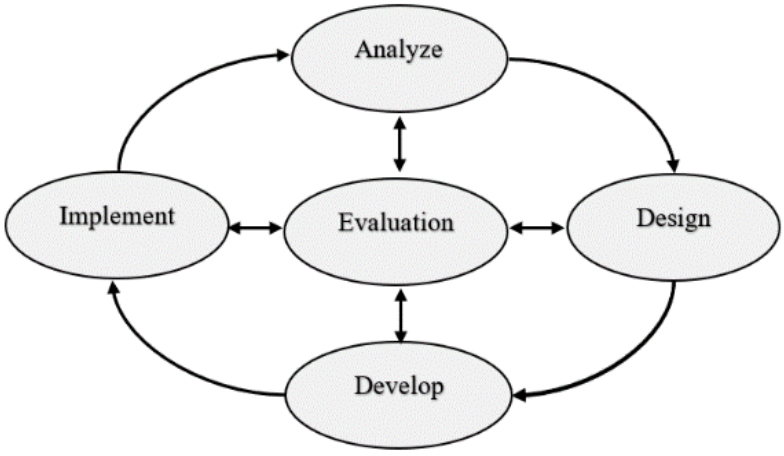

Figure 1. ADDIE Development Model

This stage consists of needs analysis and competency and content analysis. The needs analysis stage starts with conducting interviews with biology teachers using interview sheets and analyzing the needs of students using questionnaire sheets. The design stage consists of activities to create initial media concepts and design media. The next stage is development. This stage consists of product development, development of assessment instruments, expert validation, and first-stage revision. Website media that has been revised in the first stage is carried out with limited implementation to students of class XI South Konawe Senior High School 10, totaling 18 people, as well as an assessment by a biology teacher. Evaluation is applied at each stage of the ADDIE model, namely the analysis, design, development, and implementation stages.

Quantitative data analysis refers to the questionnaire that uses the Likert scale shown in Table 1 below.

Table 1. Likert Scale Categories in the Product Feasibility and Practicality Questionnaire

No.	Scale	Category
1	4	Very Good
2	3	Good
3	2	Less Good
4	1	Very Less

The survey data, in the form of average scores for each aspect, were then interpreted using the criteria for assessing the suitability and practicality of web-based instructional media, as shown in Table 2 below.

Table 2. Criteria for Assessing the Feasibility and Practicality of the Product

No.	Score Interval	Score Interval	Category
1	Mi + 1.5 SDi ≤ M ≤ Mi + 3.0 SDi	3.25 ≤ x ≤ 4	Very Good
2	Mi + 0 SDi ≤ M ≤ Mi + 1.5 SDi	2.5 ≤ x < 3.24	Good
3	Mi – 1.5 SDi ≤ M ≤ Mi + 0 SDi	1.75 ≤ x < 2.5	Less Good
4	Mi - 0 SDi ≤ M ≤ Mi + 1.5 Sdi	1 ≤ x < 1.75	Very Less

RESULTS AND DISCUSSION

Results

The results of research on website media on environmental change material carried out using the ADDIE model will be explained as follows:

Analyze

During the analysis phase, it became evident that current teaching materials are ineffective in presenting abstract and contextual concepts related to environmental change. Teachers need more engaging and interactive learning materials, while students require materials that integrate text, images, videos, and supporting resources to facilitate conceptual understanding. In addition, the learning content must align with the Merdeka Curriculum, particularly the Learning Outcomes and Learning Objectives, which are then integrated into the website design. These findings serve as the foundation for the next phase (the design phase), which involves the creation of web-based teaching materials on the topic of environmental change.

Design

The design phase translates the characteristics of environmental change—which take the form of abstract and complex biological concepts—into visual and interactive learning components. This design is guided by Cognitive Theory of Multimedia Learning, specifically the principles of signaling, coherence, and segmentation. Written explanations are combined with relevant images and videos to illustrate environmental phenomena and clarify the relationships between causes, processes, and effects. Key information is visually highlighted to direct students'

attention to essential concepts, while irrelevant visual and verbal elements are minimized to reduce unnecessary cognitive processing. The content is also organized into structured sections and supported by an interactive menu to facilitate navigation and step-by-step understanding. These design principles were implemented using Canva to develop visual elements and Google Sites to organize learning content, multimedia resources, and assessment activities. The design outcome is presented in the storyboard shown in Figure 2.

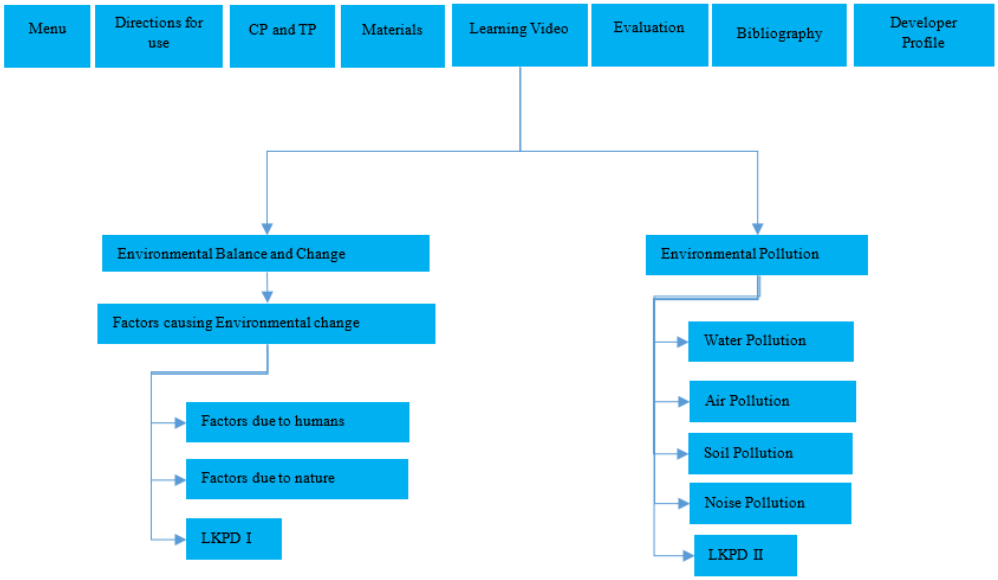

Figure 2. Storyboard of Web-based Learning Media

Development

This development phase was successfully completed by creating the first version of the web-based learning materials and conducting an evaluation or validation of those materials (which involved assessments by subject matter experts, media specialists, and biology teachers, as well as feedback from students).

1. Results of Making *Website-Based* Learning Media

Making website-based learning media products using 2 software programs, including Google Sites and Canva.

Figure 3. Website-Based Learning Media

2. Results of Feasibility and Practicality of *Website-Based* Learning Media Products

The feasibility of website-based learning media products was assessed by material expert lecturers and media experts. Material experts are faculty lecturers of the Faculty of Mathematics and Natural Sciences, Yogyakarta State University, with expertise in environmental change who are mandated to assess the feasibility of products in the realm of material. Aspects of the material assessed by material experts include the feasibility of material and language (Table 3), as follows:

Table 3. Results of Validation of the Feasibility of Website-Based Learning Media by Material Experts

No.	Assessment Aspect	Score	Criteria
1	Material feasibility	4	Very Good
2	Language	4	Very Good
Average score		**4**	**Very Good**

The presentation of the website-based instructional media product, as evaluated from all perspectives—including the appropriateness of content and language—falls into the "very good" category. The total scores for each aspect indicate that the website-based instructional media product is suitable for pilot testing with a "very good" rating. In addition to the score assessment, subject matter experts also provided suggestions for improvements to several elements of the website-based educational media materials so that the identified shortcomings can be addressed before the product is tested (Table 4), as follows:

Table 4. Input from Material Experts and Follow-up Improvements

No.	Enter	Corrective Follow-up
1	Fonts are not the same	Corrected as per feedback
2	Font size needs to be enlarged	Corrected as per feedback
3	Some links cannot be opened (instructions for use)	Corrected as per feedback
4	There is a link that does not open directly to the PDF file (landslide)	Corrected as per feedback

Media experts are faculty lecturers of the Faculty of Mathematics and Natural Sciences, Yogyakarta State University with expertise in Technology Science (IT) who are mandated to assess product feasibility in the media domain. Media aspects assessed by experts include aspects of screen design appearance, ease of use, consistency, usefulness, and graphics (Table 5), as follows:

Table 5. Results of Validation of Feasibility of Website-Based Learning Media by Media Experts

No.	Assessment Aspect	Score	Criteria
1	Display screen design	3	Good
2	Ease of use	3.5	Very Good
3	Consistency	3	Good
4	Expediency	3.4	Very Good
5	Graphics	3	Good
Average score		**3.18**	**Good**

Table 6. Input from Media Expert and Follow-up Improvement

No.	Enter	Corrective Follow-up
1	Less color contrast	Corrected as per feedback
2	The letters are not thick enough, or the font is enlarged	Corrected as per feedback
3	There are spaces between paragraphs in the material	Corrected as per feedback
4	Articles related to the impact of development	Corrected as per feedback
5	What are the causes of environmental change (video 1)	Corrected as per feedback
6	Impact of environmental change (video 1)	Corrected as per feedback
7	Efforts to minimize impact (video 1)	Corrected as per feedback
8	Learning objectives adjusted to CP and evaluation questions adjusted to TP	Corrected as per feedback

There is one biology teacher from South Konawe State High School 10. The teacher teaches in class X Merdeka I and validates the practicality of the product based on their expertise as learning practitioners at the high school level. The aspects assessed by the biology teacher include aspects of content, language, usefulness, and graphics (Table 7), as follows:

Table 7. Results of Validation of the Feasibility of Website-Based Learning Media by Biology Teacher Experts

No.	Assessment Aspect	Score	Criteria
1	Contents	3	Good
2	Language	3.2	Good
3	Expediency	3	Good
4	Graphics	3	Good
Average score		**3.05**	**Good**

The presentation of this web-based instructional media product across all aspects—including content, language, functionality, images, and learning methods—falls into the "good" category. The total score for each aspect indicates that this web-based instructional media product is worthy of being evaluated in the "good" category. Biology teachers believe that this web-based instructional medium can be used with some improvements.

Based on the improvements suggested by the teacher, the educational website can be used with several improvements in the areas of content, language, usability, and graphics. In terms of content, improvements were made by clarifying the presentation of the material, aligning the material with learning objectives, and supplementing the material with supporting media and assessment exercises. In terms of language, improvements were made by simplifying sentences, correcting spelling and scientific terminology, and using language that is communicative and appropriate for the students' level of understanding.

In terms of usability, improvements were made by clarifying the menu structure and navigation, ensuring that all links and features function properly, and optimizing the website's display to make it easily accessible across various devices. Meanwhile, regarding the graphic design, improvements were made by refining the layout, adjusting the size of images and videos, standardizing font types and sizes, and improving color combinations and the quality of visual elements to make the website more appealing, user-friendly, and conducive to the readability of the content.

There were 18 students in class XI of South Konawe State High School 10 who had studied environmental change material in the previous year. Each learner responded to the practicality of web-based learning media products in the limited trial. The aspects assessed by students include aspects of content, language, usefulness, and graphics (Table 8), as follows:

Table 8. Results of Assessment of Practicality of Website-Based Learning Media by Students

No.	Assessment Aspect	Score	Criteria
1	Contents	3.22	Good
2	Language	3.22	Good
3	Expediency	3.24	Very Good
4	Graphics	3.24	Very Good
Average score		**3.23**	**Good**

The evaluation results for the web-based educational media product indicate that the content elements are rated as good, the linguistic elements are rated as good, the usability elements are rated as very good, and the graphic elements are rated as very good. The total score for each element also indicates that this web-based educational media product is worthy of consideration in the "good" category. Unlike the evaluations by experts and biology teachers, students did not provide suggestions for improving the media or content of the web-based educational media product.

Implementation

The implementation stage is obtained from the implementation of learning. The results of learning implementation were obtained from observations made by observers at each meeting. Observations were made in both experimental classes, and the results can be seen in Table 9 below:

Table 9. Recapitulation of Learning Implementation in Experimental

No.	Class	Meeting	Activities	Total	Percentage
1	Experiment	Ke-1	10	11	91%
		Ke-2	11	11	100%

From the information contained in Table 10 regarding the results of learning implementation, it can be concluded that the implementation of learning has gone very well and follows the contents of the learning module that has been prepared. It's just that during the first meeting, the researcher did not convey the learning activities at the next meeting, because the time had run out, so the learning activities at the next meeting were conveyed through the WhatsApp group. Learning that has been carried out faces obstacles, such as students who do not have cellphones or cellphones of students who do not support using website-based learning media. Obstacles encountered in the implementation of learning can be overcome by giving instructions to students to join their classmates who have mobile phones or have supported using website media. This website media can also be used when students want to study environmental change material, so that students who do not have a cellphone or support can use their parents' cellphones to open learning materials on the website. Through web-based learning media, learning materials can be accessed anytime and from anywhere (Akpen et al., 2024; Amelia & Asikin, 2018; Songkram, 2015). In addition, this web-based media serves as a learning platform that allows both teachers and students to engage in learning activities without being limited by time or place (Indriani et al., 2023). E-learning resources can be more comprehended as an educational method that incorporates information technology through computers that have telecommunications capabilities (internet, intranet, extranet) and multimedia elements (graphics, audio, video) as the primary tools for delivering content and facilitating communication between teachers and learners (Suryaningrat et al., 2023).

Evaluation

The evaluation stage is applied to the 4 stages of the development model, namely the analysis, design, development, and implementation stages. The evaluation process is carried out at the end of each of these stages to assess the suitability of the product specifications carried out and the suitability of the results obtained as a reference and consideration for the research process at the next stage (Table 10), below:

Table 10. Evaluation Results at the Analysis, Design, Development, and Implementation Stages

No.	Stage	Evaluation Results
1	Analysis	• Each step in the analysis stage was carried out according to the established procedure. • The analysis stage included interviews with biology teachers, student needs analysis, and curriculum and content analysis. The results showed that the existing learning media were less effective in presenting abstract and contextual concepts of environmental change. Teachers needed more engaging and interactive learning materials, while students needed materials integrating text, images, videos, and supporting resources. The learning content was also aligned with the Merdeka Curriculum, particularly the Learning Outcomes and Learning Objectives. • The results of the analysis stage served as the basis for the design stage, particularly in determining the characteristics of the website-based learning media and the environmental change content to be developed.

No.	Stage	Evaluation Results
2	Design	• Each step in the design stage was carried out according to the established procedure. • The design stage focused on translating the abstract and complex characteristics of environmental change concepts into visual and interactive learning components. The design incorporated the signaling, coherence, and segmentation principles of the Cognitive Theory of Multimedia Learning. • The design results included the organization of learning materials, images, videos, interactive menus, and assessment activities using Canva and Google Sites. The resulting storyboard and media design served as the basis for the development stage.
3	Development	• Each step in the development stage was carried out according to the established procedure. • The development stage resulted in the initial website-based learning media developed using Google Sites and Canva, followed by evaluation through material expert validation, media expert validation, biology teacher assessment, and student assessment. • Material experts rated the product 4.00 (Very Good) for material feasibility and language. Media experts gave an average score of 3.18 (Good), while the biology teacher gave an average score of 3.05 (Good). Student assessment produced an average score of 3.23 (Good). • The development stage also included revisions based on expert and biology teacher feedback, including improvements to font size, links, color contrast, paragraph spacing, video content, learning objectives, navigation, and visual elements. • The revised product was subsequently used in the implementation stage.
4	Implementation	• Each step in the implementation stage was carried out according to the established procedure. • The implementation stage involved the use of the website-based learning media in learning activities. Learning implementation reached 91% in the first meeting and 100% in the second meeting, indicating that the learning activities were implemented very well and followed the prepared learning module. • Several technical obstacles were identified, including students who did not have mobile phones or whose devices were incompatible with the website-based learning media. These obstacles were addressed by having students work with classmates who had compatible devices or use parents' devices to access the learning materials. • The implementation results can serve as a reference for further research, particularly through trials on a broader scale, as the current implementation was conducted on a limited scale.

In Table 10, each step in the process of researching and developing web-based learning media has been carried out and implemented in accordance with the established guidelines. The evaluation of each step indicates that the results of each phase from analysis, design, and development to implementation can serve as a guide for proceeding to the next phase or as a foundation for further investigation. The results of the analysis regarding the needs of teachers, students, and the curriculum were used as the basis for the design process to create more effective web-based learning media. The design of media features, materials, and learning tools is adjusted to the needs that exist in learning; novelty in references is needed to support learner literacy to better understand the material studied. After the website-based learning media is designed

according to the needs in learning or school, followed by product validation by experts, the results of validation or revision are used as a reference for implementation. The implementation of learning can be used as a reference for further research or repetition on a different scale.

Discussion

This study aims to develop a web-based biology learning tool on environmental change and to evaluate the extent to which the tool is appropriate, practical, and easy to use in the learning process. The results show that the web-based learning tool developed using the ADDIE model is appropriate and easy to use in high school biology education, particularly regarding the topic of environmental change. However, these findings must be considered in light of the small sample size, as the pilot study involved only 18 students. The relatively small sample size limits the generalizability of the research results; thus, the findings regarding the practicality and feasibility of the media cannot yet be fully generalized to a broader population of high school students. Therefore, future research needs to involve a larger number of students and a more diverse range of school characteristics to obtain stronger evidence regarding the practicality, feasibility, and application of web-based learning media in a broader learning context. During the analysis phase, the results of interviews with teachers and the analysis of student needs indicated that the biology learning process still relies on traditional media, which are less effective in fostering understanding of abstract and contextual concepts, such as environmental change. This finding aligns with the views of Wahyuni & Sudarma (2018), who state that the application of information and communication technology in the learning process can overcome barriers related to space, time, and the types of learning media used. Therefore, the development of web-based learning media is an appropriate solution to meet learning needs in this digital age.

Evaluations by experts in this field indicate that the content and language are of very high quality. This suggests that the material on environmental change provided on the website aligns with learning objectives, is well-structured, and uses terminology that is easily understood by students. Improvements made based on expert recommendations, such as standardizing font type and size and strengthening hyperlinks, have also contributed to enhancing content quality. These findings align with Sudarisman (2015) perspective, which emphasizes the importance of presenting biology instruction in a structured and contextual manner so that students can understand the connection between concepts and real-world environmental phenomena.

Assessments by media experts indicate that the website-based learning tool falls into the “good” category, with “very good” ratings for ease of use and benefits. This suggests that the developed website features intuitive navigation, an appealing design, and supports effective learning processes. Improvements have been made to color contrast, font weight, and the completeness of video content to enhance the visual quality and readability of the media. Web-based learning media can provide a more interactive learning experience and increase student participation (Harahap et al., 2024).

Evaluations by biology teachers indicate that the web-based learning media performed well across all assessed aspects. Teachers found the media easy to use, well-suited to students’ characteristics, and capable of supporting both independent and in-class learning. This suggests that the developed learning media have the potential for sustained implementation in biology instruction. These findings align with the results of Tambunan & Siagian (2022) study, which revealed that digital learning media can assist teachers in designing more interactive and efficient lessons.

Students’ responses to the web-based learning media received ratings ranging from good to very good, particularly regarding usability and graphic design. Students found the media engaging, easy to understand, and helpful in grasping material on environmental change. The absence of improvement suggestions from students indicates that the learning media meets the needs and characteristics of Generation Z, who are generally already accustomed to digital technology (Irnawati & Rahmawan, 2024). This reinforces the finding that using a website as a learning medium can enhance students’ motivation and independence in the learning process.

During the implementation stage, observations showed that learning using website-based learning media went very well. The percentage of learning implementation reached 91% in the first

meeting and 100% in the second meeting. Although there were technical obstacles such as limitations in the ownership and specifications of students' devices, these obstacles could be overcome through cooperation among students. These findings are in line with Amelia & Asikin (2018), who state that web-based learning allows students to access materials anytime and anywhere, thus providing flexibility in supporting the learning process.

Overall, the findings of this study make an important contribution to the field of educational technology, particularly in the creation of website-based digital learning media for biology lessons. The media created not only helps achieve learning objectives but also enhances digital literacy, self-directed learning, and students' awareness of environmental change issues. However, this study has limitations because its implementation is still on a limited scale. Therefore, it is recommended to conduct further studies with pilot tests on a broader scale and to evaluate the quantitative impact of web-based learning media on academic achievement.

CONCLUSION

This study developed a website-based biology learning resource on environmental change for 10th-grade students using the ADDIE model. The development process was conducted systematically through analysis of teacher and student needs, curriculum and content analysis, design, development, implementation, and evaluation. The findings indicate that the developed learning resource is feasible and practical for supporting biology learning, as reflected in the assessments of subject matter experts, media experts, biology teachers, and students, particularly in terms of content, language, usability, and visual presentation. The implementation of the learning resource also showed that the learning activities could be conducted in accordance with the prepared learning procedures and supported more interactive and flexible learning. However, its use was influenced by contextual constraints, particularly the availability and compatibility of students' digital devices, which were addressed through shared access to compatible devices or parents' devices. Therefore, the developed website-based learning resources can serve as an alternative digital resource for teaching environmental change in high school biology, particularly as a complementary resource for classroom and independent learning. Further research is recommended to conduct broader-scale implementation and examine its effects on students' learning outcomes and other relevant educational variables.

REFERENCES

Akpen, C. N., Asaolu, S., Atobatele, S., Okagbue, H., & Sampson, S. (2024). Impact of online learning on student's performance and engagement: A systematic review. *Discover Education*, *3*(205), 1-15. https://doi.org/10.1007/s44217-024-00253-0

Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' perceptions of technology integration in teaching-learning practices: A systematic review. *Frontiers in Psychology*, *13*(920317), 1-9. https://doi.org/10.3389/fpsyg.2022.920317

Amelia, T., & Asikin, N. (2018). Media pembelajaran berbasis web pada mata kuliah biologi sel: Kajian dari aspek validitas. *Pedagogi Hayati*, *2*(1), 33-37. https://doi.org/10.31629/ph.v2i1.271

Dinc, E. (2017). Web-based education and accessibility. *International Journal of Technology in Education and Science*, *1*(1), 29-35. https://doi.org/10.46328/ijtes.1796

Efendi, G. F. A, Widiyanti, & Tuwoso. (2026). Development of interactive media based on Google Sites for independent learning of extracurricular computer-aided design and drafting students. *Jurnal Inovasi Teknologi Pendidikan*, *13*(1), 1-13. https://doi.org/10.21831/jitp.v13i1.85559

Ferdiansyah, F., & Irfan, D. (2021). Interactive learning media based on website in vocational school. *Al-Ishlah: Jurnal Pendidikan*, *13*(1), 755-762. https://doi.org/10.35445/alishlah.v13i1.591

Fitrianingsih, A., Hasanudin, C., Fitriyana, N., & Saadoon, A. (2023). Developing website-based learning media to improve students' 5cs skills. *AL-ISHLAH: Jurnal Pendidikan*, *15*(4), 4772–4780. https://doi.org/10.35445/alishlah.v15i4.4504

Harahap, A. N., Nurdalilah, N., & Lubis, S. S. (2024). Development of web-based learning media using Google Sites for lines and angles. *JDIME: Journal of Development and Innovation in Mathematics Education*, *2*(1), 26–36. https://doi.org/10.32939/jdime.v2i1.4116

Hidayat, H., Hidayat, O. S., & Widiasih, W. (2023). Development of Google Sites-based learning resources to improve mastery of concepts and process skills in electrical circuit materials. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4624–4631. https://doi.org/10.29303/jppipa.v9i6.3612

Indriani, N. C. L., Mustaji, M., & Mariono, A. (2023). The influence of web-based learning on students' self-regulated learning in high school chemistry learning. *International Journal of Educational Research Review*, *8*(2), 257-267. https://doi.org/10.24331/ijere.1249689

Irnawati, I., & Rahmawan, S. (2024). Development of Weebly-based website learning media containing ethnochemical acid-base material. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *12*(2), 316-327. https://doi.org/10.33394/j-ps.v12i2.10279

Jayawardana, H. B. A., & Gita, R. S. D. (2020). Inovasi pembelajaran biologi di era revolusi industri 4.0. *Prosiding Seminar Nasional Biologi*, *6*(1), 58-66. https://doi.org/10.24252/psb.v6i1.15544

Kuswanto, J. (2018). Media pembelajaran berbasis web pada mata pelajaran biologi kelas X. *Jurnal Perspektif Pendidikan*, *12*(2), 11-20. https://doi.org/10.31540/jpp.v12i2.203

Laili, A. M., Widarti, H. R., Puspita, A. P. I., Anantayani, A., Amrullah, N. K., & Aini, R. G. (2025). Development of Google Sites-based learning media to increase student learning interest. *IJCER (International Journal of Chemistry Education Research)*, *9*(2), 165–175. https://doi.org/10.20885/ijcer.vol9.iss2.art6

Maritsa, A., Hanifah Salsabila, U., Wafiq, M., Rahma Anindya, P., & Azhar Ma'shum, M. (2021). Pengaruh teknologi dalam dunia pendidikan. *Al-Mutharahah: Jurnal Penelitian Dan Kajian Sosial Keagamaan*, *18*(2), 91–100. https://doi.org/10.46781/al-mutharahah.v18i2.303

Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review*, *36*(8), 1-25. https://doi.org/10.1007/s10648-023-09842-1

Najjar, N., Rouphael, M., Bitar, T., & Hleihel, W. (2025). The rise and drop of online learning: Adaptability and future prospects. *Frontiers in Education*, *10*, 01-14. https://doi.org/10.3389/feduc.2025.1522905

Nanda, E. H., & Agustini, R. (2023). Development of website-based learning media on reaction rate material to improve student learning outcomes. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(4), 565-578. https://doi.org/10.33394/hjkk.v11i4.8523

Nurwendah, A. S., Sanjaya, Y., & Kusumastuti, M. N. (2023). Pengembangan modul ajar materi perubahan lingkungan tema sampah plastik. *Jurnal Biotek*, *11*(2), 123–143. https://doi.org/10.24252/jb.v11i2.41918

Purba, B. E. P., Riris, I. D., & Muchtar, Z. (2021). Development of website-based learning media integrated inquiry learning strategies in learning thermochemical matter chemistry.

Budapest International Research and Critics in Linguistics and Education (BirLE) Journal, *4*(1), 454–461. https://doi.org/10.33258/birle.v4i1.1658

Said, S. (2023). Peran teknologi digital sebagai media pembelajaran di era abad 21. *Jurnal PenKoMi: Kajian Pendidikan dan Ekonomi*, *6*(2), 194-202. https://doi.org/10.33627/pk.62.1300

Salsabila, F., & Aslam, A. (2022). Pengembangan media pembelajaran berbasis web Google Sites pada pembelajaran IPA sekolah dasar. *Jurnal Basicedu*, *6*(4), 6088–6096. https://doi.org/10.31004/basicedu.v6i4.3155

Saputra, H., Octaria, D., & Isroqmi, A. (2022). Pengembangan media pembelajaran berbasis web Google Sites pada materi turunan fungsi. *Jurnal Derivat: Jurnal Matematika dan Pendidikan Matematika*, *9*(2), 123-135. https://doi.org/10.31316/jderivat.v9i2.4072

Setyadi, D., & Qohar, D. A. (2017). Pengembangan media pembelajaran matematika berbasis web pada materi barisan dan deret. *Kreano*, *8*(1), 1–7. https://doi.org/10.15294/kreano.v8i2.5964

Songkram, N. (2015). E-learning system in virtual learning environment to develop creative thinking for learners in higher education. *Procedia - Social and Behavioral Sciences*, *174*, 674–679. https://doi.org/10.1016/j.sbspro.2015.01.600

Soussi, K. (2020). Web-based learning: Characteristics, practices, challenges, and recommendations. *International Journal of Science and Research*, *9*(3), 936-943. https://doi.org/10.21275/SR20312135240

Sudarisman, S. (2015). Memahami hakikat dan karakteristik pembelajaran biologi dalam upaya menjawab tantangan abad 21 serta optimalisasi implementasi kurikulum 2013. *Jurnal Florea*, *2*(1), 29-35. https://doi.org/10.25273/florea.v2i1.403

Suryaningrat, R. R., Basrowi, B., & Rahmadani, K. (2023). Pengembangan media pembelajaran interaktif pada pembelajaran IPA berbasis website di SMPN 6 Cilegon. *Jurnal PTI (Pendidikan dan Teknologi Informasi) Fakultas Keguruan Ilmu Pendidikan Universita Putra Indonesia" YPTK" PADANG*, *10(2)*, 62-68. https://doi.org/10.35134/jpti.v10i2.175

Tambunan, M. A., Siagian, P., & Kunci, K. (2022). Pengembangan media pembelajaran interaktif berbasis website (Google Sites) pada materi fungsi di SMA Negeri 15 Medan. *Humantech: Jurnal Ilmiah Multidisiplin Indonesia*, *1*(10), 1520-1533. https://doi.org/10.32670/ht.v1i10.2166

Wahyuni, I., & Sudarma, T. F. (2018). Design of learning media physics based on website. *Journal of Physics: Conference Series*, *1120*, 1-14. https://doi.org/10.1088/1742-6596/1120/1/012097

Warsita, B. (2017). The roles and challenges of Instructional technology professional developers in the 21st century Learning. *Kwangsan: Jurnal Teknologi Pendidikan*, *5*(2), 77-90. https://doi.org/10.31800/jtp.kw.v5n2.p77--90

Yanto, R., Waskito, W., Effendi, H., & Purwanto, W. (2023). Development of web-based learning media using Google Sites in vocational high school informatics subjects. *Journal of Vocational Education Studies*, *6*(1), 11–24. https://doi.org/10.12928/joves.v6i1.8027

Yuda, Y. P., Azis, M. N. L., & Kurniawati, I. D. (2019). The designing of website-based learning media as an alternative for online learning for student practicing at SMKN 1 Sawoo Ponorogo. *Journal of Physics: Conference Series*, *1381*, 1-7. https://doi.org/10.1088/1742-6596/1381/1/012016

Zou, Y., Kuek, F., Feng, W., & Cheng, X. (2025). Digital learning in the 21st century: Trends, challenges, and innovations in technology integration. *Frontiers in Education*, *10*, 01-11. https://doi.org/10.3389/feduc.2025.1562391

Zulaiha, Z., Hartono, H., & Siahaan, S. M. (2025). Needs analysis for the development of web-based learning multimedia context climate change issues environmental issues content to support junior high school students' literacy. *Journal of Innovation and Research in Primary Education*, *4*(3), 1481–1490. https://doi.org/10.56916/jirpe.v4i3.1596

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (243-253)
Online: http://journal.uny.ac.id/index.php/jitp

The effect of Moodle-based adaptive e-learning on self-regulated learning and cognitive learning outcomes

Muafid Ardiansyah*, Herman Dwi Surjono
Universitas Negeri Yogyakarta, Indonesia.
* Corresponding Author. E-mail: muafidardiansyah.2024@student.uny.ac.id

ARTICLE INFO

Article History
Received:
21 April 2026;
Revised:
6 June 2026;
Accepted:
6 June 2026;
Available online:
30 June 2026.

Keywords
Adaptive e-learning; Learning outcome; Moodle; Self-regulated learning

ABSTRACT

This study aims to develop a Moodle-based adaptive e-learning system and examine its effectiveness in improving students' self-regulated learning and cognitive learning outcomes. This study employed a Research and Development method using the Alessi and Trollip model, which includes the stages of planning, design, and development. The research subjects were eleventh-grade students, divided into experimental and control groups. The research instruments included a self-regulated learning questionnaire adapted from the SRL-O, cognitive achievement tests, and expert validation. Data were analyzed using MANOVA and univariate tests. The results indicate that the developed adaptive e-learning system is highly feasible, with average scores of 4.78 from content experts and 4.82 from media experts. Meanwhile, user evaluations yielded scores of 4.34 and 4.27, both categorized as feasible. Empirically, the MANOVA results showed a significant difference between the experimental and control groups. These findings were supported by univariate tests, which revealed a large effect on self-regulated learning and a moderate effect on cognitive learning outcomes. This study recommends the implementation of Moodle-based adaptive e-learning to support differentiated instruction and enhance students' independent learning.

How to cite:
Ardiansyah, M., & Surjono, H. D. (2026). The effect of Moodle-based adaptive e-learning on self-regulated learning and cognitive learning outcomes. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 243-253. https://doi.org/10.21831/jitp.v13i2.97153

INTRODUCTION

The rapid advancement of digital technology has transformed education by supporting 21st-century learning, which emphasizes critical thinking, creativity, collaboration, communication, and self-directed learning (van Laar et al., 2017). This transformation has shifted educational practices from teacher-centered toward student-centered learning, requiring learners to take greater responsibility for managing their own learning processes (Adnan, 2020; Fajri et al., 2021). Consequently, educational technology is expected not only to facilitate knowledge acquisition but also to promote lifelong learning competencies that enable students to adapt to continuously changing learning environments.

Personalized learning has become an important approach for addressing differences in students' needs, abilities, and learning progress (Naseer et al., 2024). Through technology-supported learning environments, students can access learning resources flexibly while receiving learning experiences that better match their individual characteristics (Bashir & Lapshun, 2025; Chukwuemeka-Nworu et al., 2024). Recent evidence also indicates that digital learning enhances accessibility, engagement, and personalization, although its effectiveness depends on adequate

technological infrastructure and digital connectivity (Zou et al., 2025; Bendo & Alviar, 2026). Therefore, the integration of adaptive digital technologies should be accompanied by instructional design that actively supports students' learning processes.

Despite these developments, classroom instruction in many schools continues to rely on teacher-centered approaches that provide limited opportunities for students to actively regulate their own learning (Fitriasari & Sari, 2018; Shemshack & Spector, 2020). Such learning environments often position students as passive recipients of information rather than active participants in constructing knowledge, limiting the development of learning independence. As a result, students' self-regulated learning (SRL) remains insufficiently developed.

Self-regulated learning refers to learners' ability to plan, monitor, and evaluate their own learning activities to achieve academic goals (Zimmerman, 2002). According to Zimmerman, SRL develops through three cyclical phases: forethought, performance, and self-reflection. Therefore, effective digital learning environments should not only provide learning materials but also facilitate goal setting, continuous monitoring, timely feedback, and reflection to support these self-regulatory processes.

E-learning has been widely adopted as a digital learning solution in schools. However, many existing implementations primarily function as repositories for learning materials without providing adaptive learning pathways or personalized feedback (Nguyen & Nguyen, 2023). Consequently, the potential of e-learning to facilitate self-regulated learning has not been fully realized. Adaptive e-learning addresses this limitation by dynamically adjusting learning content, sequencing, and feedback according to learners' characteristics and performance, thereby providing more individualized learning experiences (Olusegun & Brighwood, 2024).

An Adaptive Learning System (ALS) enables this personalization through the interaction of three core components: the learner model, content model, and adaptation model (Vagale et al., 2020). The learner model represents students' characteristics and learning progress, the content model organizes instructional resources, while the adaptation model determines how learning materials, navigation, and feedback are dynamically delivered according to learner needs (Martin et al., 2020). Such mechanisms allow adaptive e-learning to function not only as a content delivery platform but also as an instructional support system for self-regulated learning.

Previous studies consistently demonstrate that adaptive e-learning improves learning outcomes, learning engagement, and motivation compared with conventional e-learning (El-Sabagh, 2021; Ristić et al., 2023). Research has reported positive findings in mathematics learning (Awang et al., 2024), adaptive feedback systems (Mejeh et al., 2024), AI-based adaptive learning environments (Lin et al., 2025), and structured Moodle learning environments that support SRL (Bellhauser et al., 2022; Satriani et al., 2024; Núñez et al., 2011). Other studies have also shown that SRL-oriented e-learning improves learning outcomes despite the absence of adaptive mechanisms (Arifin & Marini, 2022; Wahyuni et al., 2020). Collectively, these findings suggest that adaptive learning and SRL are closely related; however, they have generally been investigated separately or implemented on specialized platforms rather than learning management systems commonly used in schools.

Accordingly, an important research gap remains. Few studies have integrated adaptive learning mechanisms within Moodle specifically to facilitate SRL among senior high school students while simultaneously examining their effects on both self-regulated learning and cognitive learning outcomes. As a result, empirical evidence regarding the effectiveness of adaptive Moodle-based learning in supporting students' learning independence within authentic school contexts remains limited.

To address this gap, this study develops a Moodle-based adaptive e-learning system utilizing the conditional activities feature to generate remedial, reinforcement, and enrichment learning pathways based on students' formative assessment results (Jusuf & Andriani, 2025). The system is designed to support the phases of self-regulated learning while remaining consistent with the differentiated learning principles of the Kurikulum Merdeka. Accordingly, this study contributes in three ways: (1) integrating Moodle-based adaptive e-learning with an SRL-oriented instructional design; (2) implementing automatic adaptive learning pathways based on formative assessment

performance; and (3) evaluating the effects of the developed system on both self-regulated learning and cognitive learning outcomes among senior high school students using MANOVA.

METODE

This study employed a research and development (R&D) approach adapted from the instructional design model of Alessi & Trollip (2001), which consists of five stages: planning, design, development, implementation, and evaluation. The study was conducted at Turi 1 Senior High School, Sleman Regency, Special Region of Yogyakarta, Indonesia, from September 2025 to February 2026. The research involved two subject-matter experts, two media experts, 10 students participating in the limited trial (Beta I), and 36 students in the experimental class during the implementation stage (Beta II).

The subject-matter experts consisted of one mathematics lecturer from the Faculty of Mathematics and Natural Sciences, Yogyakarta State University, and one senior mathematics teacher from Turi 1 Senior High School. The media experts consisted of one Professor of Educational Technology from Yogyakarta State University and one educational technology developer specializing in digital learning media. These experts evaluated the accuracy of the learning content, instructional design, media quality, usability, and the adaptive learning mechanism before implementation.

Before the quasi-experimental implementation, the developed adaptive e-learning system underwent a limited trial (Beta I) involving 10 students. This pilot testing aimed to evaluate system functionality, readability of the learning materials and instruments, usability, and technical performance. Feedback obtained during this stage was used to improve both the adaptive learning system and the research instruments before implementation in the experimental class.

The adaptive mechanism was implemented using Moodle's Conditional Activities feature. The learning system consisted of three main instructional modules, each ending with a formative assessment. Students' formative assessment results automatically determined their subsequent learning pathway. Students obtaining scores of ≤ 60 were directed to the remedial pathway, those obtaining a score of 80 accessed the reinforcement pathway, and students achieving 100 proceeded to the enrichment pathway. After completing the assigned adaptive pathway, all students completed a reflection journal before continuing to the next instructional module. This adaptive sequence was repeated across all three modules, allowing learning pathways to dynamically adjust according to students' learning performance.

The self-regulated learning instrument was adapted from Broadbent et al., (2023), consisting of two higher-order factors and ten dimensions that measure students' self-regulated learning in online and blended learning environments. The instrument comprised 40 validated items and demonstrated high reliability with a Cronbach's Alpha coefficient of 0.939. Cognitive learning outcomes were measured using a 20-item multiple-choice test. The instrument was validated by the subject-matter experts and achieved a Cronbach's Alpha coefficient of 0.726, indicating high reliability.

The collected data were analyzed using descriptive quantitative techniques to determine the feasibility level of the developed adaptive e-learning system based on evaluations from subject-matter experts, media experts, and students. Feasibility scores were converted into percentages and interpreted according to Akbar (2013) feasibility criteria.

$$P = \frac{\Sigma X}{\Sigma X max} \times 100\%$$

Where P represents the feasibility percentage, ΣX is the total obtained score, and $\Sigma x max$ is the maximum possible score. The resulting percentages were interpreted based on the feasibility criteria proposed by Akbar (2013):

Table 1. Level of Validity

No.	Score Range (100%)	Category
1	81% - 100%	Very Good
2	61% - 80%	Good
3	41% - 60%	Sufficient
4	21% - 40%	Less
5	0% - 20%	Vey Less

The effectiveness of the adaptive e-learning system was examined using a quasi-experimental design involving one experimental class and one control class. Self-regulated learning and cognitive learning outcomes were analyzed simultaneously using Multivariate Analysis of Variance (MANOVA) at a significance level of 0.05. Follow-up univariate analyses (Tests of Between-Subjects Effects) were conducted to determine the treatment effect on each dependent variable and to measure effect sizes.

RESULT AND DISCUSSION

Results

The product developed in this study is a Moodle-based adaptive e-learning system for Grade XI trigonometry, specifically the sine and cosine rules. The development was informed by a student needs analysis, school educational report data, and interviews with teachers at Turi 1 Senior High School. The adaptive mechanism was implemented using Moodle's Conditional Activities feature, which automatically adjusts learning pathways according to students' formative assessment results. The interface of the developed system is presented in Figure 1 and Figure 2.

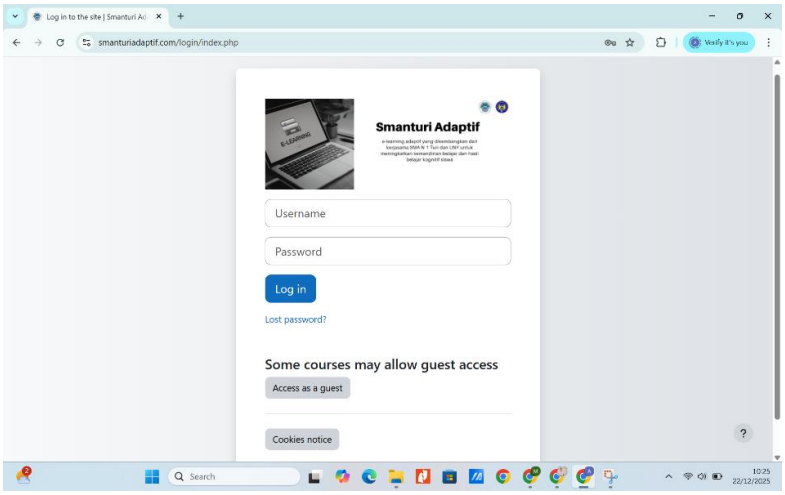

Figure 1. Adaptive E-Learning Login Page

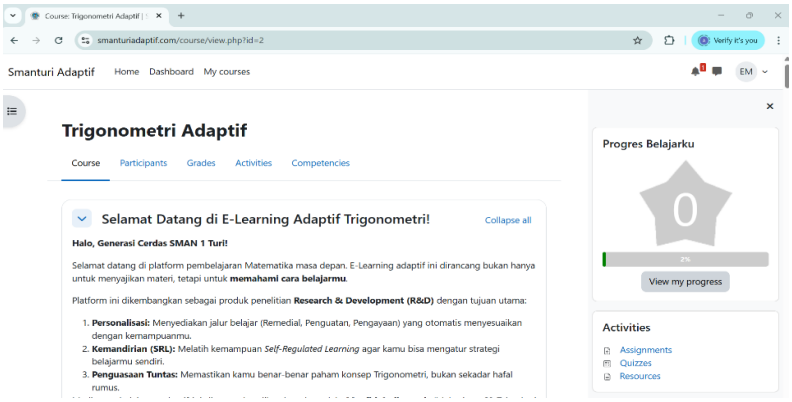

Figure 2. Trigonometry Course Interface on the Adaptive E-Learning Platform

The adaptive e-learning system provides three learning pathways: remedial, reinforcement, and enrichment, which are automatically assigned based on students' formative assessment performance. In addition, the system integrates self-regulated learning (SRL) support throughout the learning process. The *Target Belajarku* feature facilitates goal setting and learning planning, the *Progres Belajarku* dashboard enables students to monitor their learning progress, and the Jurnal Belajarku feature supports reflection upon completion of each learning module. The adaptive learning pathways are illustrated in Figure 3.

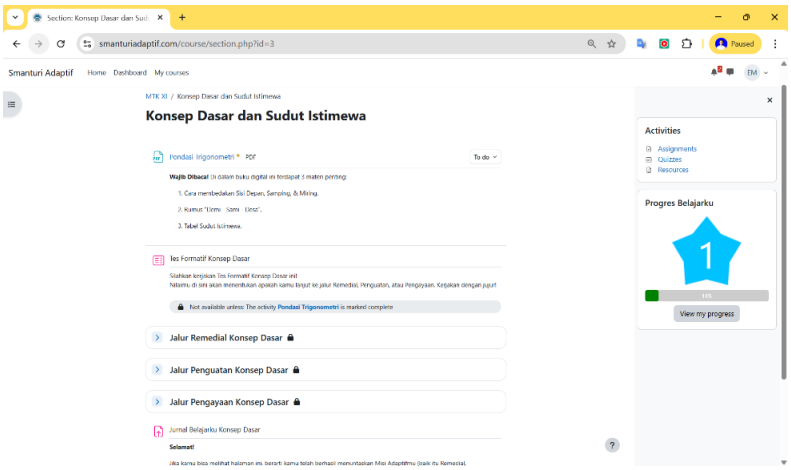

Figure 3. Adaptive Path in Adaptive E-learning

The developed product was evaluated through expert validation and user testing. The results of content validation, media validation, and student responses are summarized in Tables 2, 3, and 4, respectively.

Table 2. Results of Expert Validation on Content

No.	Aspect	Percentage	Category
1	Content Quality	96%	Very Good
2	Instructional Design	96%	Very Good
3	Adaptive Content	100%	Very Good
4	Support for SRL Content	94%	Very Good
5	Quality of Formative Test	96%	Very Good
6	Quality of Pretest and Posttest	92%	Very Good
Average		**95.6%**	**Very Good**

Table 3. Result of Expert Validation on Media

No.	Aspect	Percentage	Category
1	User Interface Design	98%	Very Good
2	User Experience	98%	Very Good
3	Adaptive Functionality	94%	Very Good
4	Support for SRL Features	96%	Very Good
5	Performance & Accessibility	96%	Very Good
Average		**96.4%**	**Very Good**

Table 4. Student Responses in Beta 1 and 2

No.	Aspect	Beta 1 (%)	Beta 2 (%)	Average (%)	Category
1	Ease of Access & Navigation	86.4%	84.8%	85.6%	Very Good
2	Quality of Content Presentation	84%	85.2%	84.6%	Very Good
3	Functionality of Adaptive Features	90.4%	86.4%	88.4%	Very Good
Average		**86.9%**	**85.5%**	**86.2%**	**Very Good**

Overall, the expert evaluations indicated that the developed adaptive e-learning achieved a very good level of feasibility across all assessed aspects, including content quality, instructional design, adaptive functionality, and support for self-regulated learning. Likewise, student responses from both Beta I and Beta II showed positive perceptions regarding accessibility, content presentation, and adaptive features, indicating that the system was appropriate for classroom implementation.

Following the feasibility evaluation, the adaptive e-learning system was implemented to examine its effectiveness in improving students' self-regulated learning and cognitive learning outcomes. The mean pretest, posttest, and gain scores for both variables are presented in Table 5.

Table 5. Mean Pretest and Posttest Scores for SRL and Cognitive Learning Outcomes

No.	Groups	SRL Pre	SRL Post	Gain SRL	Cognitive Pre	Cognitive Post	Cognitive Gain
1	Experimental	145.97	156.27	10.3	51.66	86.11	34.45
2	Control	145.44	147.91	2.47	52.97	76.76	2.79

Both groups demonstrated improvements in self-regulated learning and cognitive learning outcomes after the learning intervention. However, the experimental group consistently achieved higher gain scores than the control group for both variables, indicating greater learning improvement following the implementation of the adaptive e-learning system.

Table 6. Multivariate Analysis of Variance (MANOVA)

Effect	Multivariate Test	Value	F	Hypothesis df	Error df	p	Partial η^2
Group	Pillai's Trace	0.272	12.502	2	67	<0.001	0.0272

The multivariate analysis (MANOVA) revealed a statistically significant effect of the learning intervention on the combined dependent variables, namely self-regulated learning and cognitive learning outcomes (Pillai's Trace = 0.272, $F(2,67) = 12.502$, $p < 0.001$). The obtained Partial Eta Squared value of 0.272 indicates a large multivariate effect, suggesting that the adaptive e-learning intervention contributed substantially to the simultaneous improvement of both learning outcomes.

Table 7. Tests of Between-Subjects Effects

No.	Dependent Variable	F	p	Partial η^2	Effect Size
1	Self-Regulated Learning	16.380	<0.001	0.194	Large
2	Cognitive Learning Outcomes	4.791	0.032	0.066	Moderate

Effect size categories were interpreted based on Cohen (1988), where Partial $\eta^2 \geq 0.14$ indicates a large effect, 0.06–0.13 a moderate effect, and 0.01–0.05 a small effect. Follow-up univariate analyses confirmed significant treatment effects for both dependent variables (Table 7). The intervention produced a large effect on self-regulated learning (Partial $\eta^2 = 0.194$) and a moderate effect on cognitive learning outcomes (Partial $\eta^2 = 0.066$), indicating that the adaptive e-learning intervention had a stronger impact on students' self-regulated learning than on their cognitive learning outcomes.

Discussion

The findings demonstrate that integrating adaptive learning pathways into Moodle effectively supports both students' self-regulated learning and cognitive learning outcomes. Beyond improving academic performance, the adaptive learning environment appears to strengthen students' capacity to regulate their own learning through individualized learning pathways and continuous formative feedback. This finding suggests that adaptive learning is not merely a technological enhancement but also an instructional approach that promotes active learner engagement by providing learning experiences tailored to students' needs and performance. In this study, the automatic adjustment of remedial, reinforcement, and enrichment pathways encouraged students to participate in learning activities that matched their level of mastery, thereby creating opportunities for more meaningful and self-directed learning. Consequently, the developed adaptive e-learning system demonstrates the

potential of Moodle to support both personalized learning and the development of self-regulated learning within secondary school mathematics education.

Previous studies have consistently reported positive effects of Moodle-based learning environments on self-regulated learning and academic achievement (Núñez et al., 2011; Bellhäuser et al., 2022). The present study extends these findings by demonstrating that Moodle's built-in Conditional Activities feature can automatically generate differentiated learning pathways based on formative assessment results. Unlike previous studies that primarily evaluated general learning effectiveness (Ristić et al., 2023; Morze et al., 2021), this study simultaneously examined self-regulated learning and cognitive learning outcomes using MANOVA. These findings indicate that adaptive mechanisms embedded within widely used learning management systems can effectively operationalize personalized learning principles without requiring sophisticated AI-based platforms.

However, the effectiveness of adaptive learning environments is strongly influenced by instructional design rather than by the adaptive technology itself. Harati et al., (2024) reported a decline in students' self-regulated learning after using the ALEKS platform, which was associated with limited motivation, system complexity, low social presence, and the demanding nature of the learning environment. In contrast, the Moodle-based adaptive e-learning developed in this study employed a relatively simple adaptation mechanism using formative assessment results to provide remedial, reinforcement, and enrichment pathways. This approach allowed students to receive learning activities that matched their level of mastery without increasing the complexity of system navigation or learning tasks. These findings suggest that adaptive learning systems are more likely to support self-regulated learning when the adaptive mechanism is integrated with clear instructional guidance, manageable learning pathways, and continuous formative feedback that encourage students to regulate their own learning processes.

The stronger effect observed on self-regulated learning suggests that adaptive learning primarily influences students' learning behaviors before producing substantial improvements in academic achievement. This finding supports Zimmerman (2002) proposition that effective learning environments should first facilitate planning, monitoring, and reflection as the core processes of self-regulated learning. Similar tendencies have been reported in Moodle-based learning environments (Núñez et al., 2011; Bellhäuser et al., 2022) and AI-supported adaptive systems (Lin et al., 2025). In the present study, this stronger influence can be attributed to the integration of SRL-oriented features such as "*Target Belajarku*," "*Progres Belajarku*," and "*Jurnal Belajarku*," which explicitly support students in setting learning goals, monitoring progress, and reflecting on their learning experiences. Consequently, the adaptive e-learning environment not only personalizes content delivery but also encourages students to develop metacognitive strategies and independent learning behaviors.

In contrast, the moderate effect on cognitive learning outcomes suggests that improving conceptual understanding requires a more complex process. This aligns with Bellhäuser et al., (2022) and Huang et al., (2024), who found that SRL-based adaptive feedback has a greater impact on self-regulation than on cognitive performance directly. Studies by Awang et al., (2024) and Ristić et al. (2023) also reported improvements in learning outcomes through adaptive systems, but they did not examine the difference in effect strength between SRL and cognitive outcomes. Therefore, these findings extend previous research by suggesting that Moodle-based adaptive learning may strengthen students' self-regulation more substantially than cognitive learning outcomes during the intervention period. This finding implies that improvements in self-regulation may provide an important foundation for subsequent gains in cognitive learning, although this relationship requires further investigation. This also indicates that improvements in cognitive learning outcomes may require longer intervention durations or additional instructional strategies.

Further analysis of the SRL dimensions showed that the most prominent increases occurred in the forethought and performance phases. The greater improvement observed in the forethought and performance phases suggests that the adaptive learning design was particularly effective in supporting students' goal setting, learning management, persistence, and monitoring throughout the learning process. These competencies represent the initial stages of Zimmerman (2002) self-regulated learning cycle and provide an essential foundation for successful independent learning. Consistent with Mejeh et al., (2024) and Wahyuni et al., (2020), the present findings indicate that

integrating SRL-oriented learning activities with adaptive learning pathways can strengthen students' regulatory behaviors. The inclusion of real-time adaptive feedback further extends previous studies by providing personalized learning support within a widely used learning management system.

Meanwhile, the self-reflection phase showed relatively smaller improvement than the forethought and performance phases. This finding suggests that, although the adaptive e-learning system effectively supported students in planning, monitoring, and managing their learning activities, additional instructional support may be needed to strengthen reflective learning processes. This result is consistent with Huang et al., (2024), who reported that adaptive feedback tends to have a stronger influence on the earlier phases of self-regulated learning than on the reflection phase.

From a practical perspective, this study offers important implications for educational technology, particularly in the implementation of differentiated learning within the Merdeka Curriculum, which can be carried out automatically through the system. Adaptive e-learning enables teachers to manage diverse student abilities more efficiently without having to perform manual differentiation. In addition, from the perspective of educational management, these results indicate that the integration of adaptive technology in learning can serve as an effective strategy for improving data-driven instructional quality.

Despite these contributions, several limitations should be acknowledged when interpreting the findings. First, the study was conducted in only one senior high school with one experimental class and one control class, limiting the generalizability of the results beyond the present context. Second, self-regulated learning was measured using a self-report instrument, which may not fully capture students' actual learning behaviors during the intervention. Third, the relatively short implementation period may have limited the extent of improvement in cognitive learning outcomes. Accordingly, future research is encouraged to involve more diverse educational settings, larger participant groups, and longer intervention periods. Future studies may also integrate learning analytics derived from Moodle activity logs and develop more comprehensive reflection features or AI-supported adaptive mechanisms to further enhance personalized learning and self-regulated learning.

CONCLUSION

This study concludes that the Moodle-based adaptive e-learning system developed in this research was effective in improving self-regulated learning and cognitive learning outcomes among Grade XI students at SMA Negeri 1 Turi. The findings indicate that the integration of adaptive learning pathways through remedial, reinforcement, and enrichment activities, together with SRL-oriented features such as Target Belajarku, Progres Belajarku, and Jurnal Belajarku, supported students in planning, monitoring, and reflecting on their learning processes. Within the context of this study, the adaptive learning approach demonstrated a stronger effect on self-regulated learning than on cognitive learning outcomes, suggesting that adaptive instructional support may first strengthen students' learning regulation before producing broader academic gains.

From a practical perspective, the findings suggest that Moodle's built-in adaptive features can support the implementation of differentiated instruction in secondary school classrooms without requiring additional adaptive platforms. However, these findings should be interpreted within the context of a single-school implementation involving one experimental class and one control class over a relatively short intervention period. Therefore, caution should be exercised when generalizing the results to other educational settings.

Future studies are encouraged to examine the effectiveness of Moodle-based adaptive e-learning across multiple schools, larger and more diverse participant groups, and longer implementation periods to improve the external validity of the findings. In addition, future research may integrate learning analytics derived from LMS activity logs and explore more advanced adaptive technologies to further strengthen personalized learning and self-regulated learning support.

ACKNOWLEDGEMENTS

The author would like to express gratitude to the Educational Technology Program at Yogyakarta State University for the academic support provided throughout the research process, as well as to Turi 1 Senior High School for granting permission, providing facilities, and offering cooperation, which enabled this research to be successfully carried out.

REFERENCES

Adnan, M. (2020). Online learning amid the COVID-19 pandemic: Students perspectives. *Journal of Pedagogical Sociology and Psychology*, *1*(2), 45–51. https://doi.org/10.33902/jpsp.2020261309

Alessi, S., & Trollip, S.R. (2001). *Multimedia for learning: Methods and development* (3rd ed.). Allyn & Bacon.

Akbar, S. (2013). *Instrumen perangkat pembelajaran*. PT Remaja Rosda Karya.

Arifin, F., & Marini, A. (2022). Pemanfaatan e-learning dan pengaruhnya terhadap self regulated learning matematis siswa sekolah dasar. *JMIE (Journal of Madrasah Ibtidaiyah Education)*, *6*(2), 198–205. https://doi.org/10.32934/jmie.v6i2.457

Awang, L. A., Yusop, F. D., & Danaee, M. (2024). Insights on usability testing: The effectiveness of an adaptive e-learning system for secondary school mathematics. *International Electronic Journal of Mathematics Education*, *19*(3), 1-15. https://doi.org/10.29333/iejme/14621

Bashir, S., & Lapshun, A. L. (2025). *E-learning* future trends in higher education in the 2020s and beyond. *Cogent Education*, *12*(1). 1-15. https://doi.org/10.1080/2331186X.2024.2445331

Bellhäuser, H., Liborius, P., & Schmitz, B. (2022). Fostering self-regulated learning in online environments: Positive effects of a web-based training with peer feedback on learning behavior. *Frontiers in Psychology*, 13, 1-14. https://doi.org/10.3389/fpsyg.2022.813381

Bendo, M. C. D., & Alviar, D. C. (2026). Digital divide and educational inequality in Asia: A cross-country secondary data analysis of connectivity, access, and student achievement. *Journal of Research, Innovation, and Strategies for Education (RISE)*, *3*(6), 136–155. https://doi.org/10.70148/rise.v3i4.9

Chukwuemeka-Nworu, I. J., Chigbu, B. C., Chukwuji, C. E., & Ogbonnaya, N. O. (2024). Management of hybrid learning in resource-scarce communities in Nigerian schools. *East African Journal of Education and Social Sciences*, *4*(6), 108–119. https://doi.org/10.46606/eajess2023v04i06.0338

Broadbent, J., Panadero, E., Lodge, J. M., & Fuller-Tyszkiewicz, M. (2023). The self-regulation for learning online (SRL-O) questionnaire. *Metacognition and Learning*, *18*(1), 135–163. https://doi.org/10.1007/s11409-022-09319-6

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(53), 1-24. https://doi.org/10.1186/s41239-021-00289-4

Fajri, I., Yusuf, R., & Zailani, M. (2021). Model pembelajaran project citizen sebagai inovasi pembelajaran dalam meningkatkan keterampilan abad 21. *Jurnal Hurriah: Jurnal Evaluasi Pendidikan dan Penelitian*, *2*(3), 105–118. https://doi.org/10.56806/jh.v2i3.30

Fitriasari, P., & Sari, N. (2018). Kemandirian belajar mahasiswa melalui blended learning pada mata kuliah metode numerik. *Jurnal Elemen*, *4*(1), 1–8. https://doi.org/10.29408/jel.v4i1.439

Harati, H., Sujo-Montes, L., Tu, C.-H., Armfield, S. J. W., & Yen, C.-J. (2021). Assessment and learning in knowledge spaces (ALEKS) adaptive system impact on students' perception and self-regulated learning skills. *Education Sciences, 11*(10), 1-21. https://doi.org/10.3390/educsci11100603

Huang, J., Cai, Y., Lv, Z., Huang, Y., & Zheng, X. (2024). Toward self-regulated learning: Effects of different types of data-driven feedback on pupils' mathematics word problem-solving performance. *Frontiers in Psychology, 15*, 01-14. https://doi.org/10.3389/fpsyg.2024.1356852

Jusuf, H., & Andiani. (2025). Analysis of an adaptive e-learning system with the adjustment of the Felder–Silverman model in Moodle. *Journal of Systems Engineering and Information Technology (JOSEIT)*, *4*(1), 30–41. https://doi.org/10.29207/joseit.v4i1.6435

Lin, C. H., Kuo, B.-C., & Chang, F. T. Y. (2025). The impact of Taiwan adaptive learning platform (TALP) on self-regulated learning and mathematics achievement. *Educational Psychology*, *46*(3), 458-479. https://doi.org/10.1080/01443410.2025.2561028

Martin, F., Chen, Y., Moore, R. L., & Westine, C. D. (2020). Systematic review of adaptive learning research designs, context, strategies, and technologies from 2009 to 2018. *Educational Technology Research and Development*, *68*(4), 1903–1929. https://doi.org/10.1007/s11423-020-09793-2

Mejeh, M., Sarbach, L., & Hascher, T. (2024). Effects of adaptive feedback through a digital tool – a mixed-methods study on the course of self-regulated learning. *Education and Information Technologies*, *29*(14), 1–43. https://doi.org/10.1007/s10639-024-12510-8

Morze, N. V., Varchenko-Trotsenko, L. O., & Terletska, T. S. (2025). Comprehensive framework for adaptive learning implementation in Moodle LMS: Technical, pedagogical, and administrative perspectives. *6th International Conference on History, Theory and Methodology of Learning (ICHTML 2025)*, 196-212. https://doi.org/10.55056/ceur-ws.org/Vol-4060/paper13.pdf

Naseer, F., Khan, M. N., Tahir, M., Addas, A., & Aejaz, S. M. H. (2024). Integrating deep learning techniques for personalized learning pathways in higher education. *Heliyon, 10*(11), 1-18. https://doi.org/10.1016/j.heliyon.2024.e32628

Nguyen, H. H., & Nguyen, V. A. (2023). Personalized learning in the online learning from 2011 to 2021: A bibliometric analysis. *International Journal of Information and Education Technology*, *13*(8), 1261–1272. https://doi.org/10.18178/ijiet.2023.13.8.1928

Núñez, J. C., Cerezo, R., Bernardo, A., Rosário, P., Valle, A., Fernández, E., & Suárez, N. (2011). Implementation of training programs in self-regulated learning strategies in Moodle format: Results of an experience in higher education. *Psicothema*, *23*(2), 274–281. https://pubmed.ncbi.nlm.nih.gov/21504681/

Olusegun, J., Flypaper, D., Oluwaseyi, J. & Brightwood, S. (2024). Ai-driven adaptive learning systems: Enhancing student engagement. https://www.researchgate.net/publication/384767755_Ai-driven_adaptive_learning_systems_enhancing_student_engagement

Ristić, I., Runić-Ristić, M., Savić Tot, T., Tot, V., & Bajac, M. (2023). The effects and effectiveness of an adaptive e-learning system on the learning process and performance of students. *International Journal of Cognitive Research in Science, Engineering and Education*, *11*(1), 77–92. https://doi.org/10.23947/2334-8496-2023-11-1-77-92

Satriani, E., Zaim, M., Ermanto, Walpita, C. K., & Etfita, F. (2024). A design of learning activities that created students self-regulated learning through LMS Moodle. *International Journal of Language Pedagogy*, *4*(2), 127–137. https://doi.org/10.24036/ijolp.v4i2.79

Shemshack, A., & Spector, J. M. (2020). A systematic literature review of personalized learning terms. In *Smart Learning Environments*, *7*(33). 1-20. https://doi.org/10.1186/s40561-020-00140-9

Vagale, V., Niedrite, L., & Ignatjeva, S. (2020). Implementation of personalized adaptive e-learning system. *Baltic Journal of Modern Computing*, *8*(2), 293–310. https://doi.org/10.22364/BJMC.2020.8.2.06

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Wahyuni, A. S., Warpala, I., & Agustini, K. (2020). Pengembangan konten e-learning berbasis self regulated learning untuk meningkatkan hasil belajar airline reservation. *Jurnal Teknologi Pembelajaran Indonesia*, *10*(1), 1–12. https://doi.org/10.23887/jtpi.v10i1.3394

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zou, Y., Kuek, F., Feng, W., & Cheng, X. (2025). Digital learning in the 21st century: Trends, challenges, and innovations in technology integration. *Frontiers in Education*, *10*, 01-11. https://doi.org/10.3389/feduc.2025.1562391

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (254-263)
Online: http://journal.uny.ac.id/index.php/jitp

The effect of an adaptive scaffolding-based learning website on students' computational thinking skills

Wahyu Agil Masduki*, Achmad Imam Agung, Yeni Anistyasari, Ika Fitri Ulfindrayani, Yessy
Universitas Negeri Surabaya, Indonesia.
* Corresponding Author. E-mail: 25070895034@mhs.unesa.ac.id

ARTICLE INFO

Article History
Received:
14 June 2026;
Revised:
24 June 2026;
Accepted:
25 June 2026;
Available online:
30 June 2026.

Keywords
Adaptive learning; Computational thinking; Learning media; Scaffolding; Technology-enhanced learning; Web-based learning

ABSTRACT

Computational Thinking (CT) learning in Informatics may be challenging when students begin with different levels of competence, while uniform task difficulty and support do not adequately address these differences. An adaptive scaffolding-based learning website offers a possible solution by adjusting learning levels and providing progressive assistance according to students' initial competence. This study examined the effect of the website on the CT skills of Grade X students. A quantitative quasi-experimental study with a nonequivalent control group pretest-posttest design involved 72 students, comprising 36 students in the experimental group and 36 in the control group. The experimental group used the adaptive scaffolding-based website, whereas the control group received conventional instruction through teacher explanations, classroom discussions, practice questions, and assignments without the adaptive website or tiered hints. Data were analyzed using N-Gain, normality and homogeneity tests, an independent-samples t-test, and Cohen's d. The experimental group obtained a higher mean N-Gain than the control group (0.58 vs. 0.36), with a statistically significant difference ($p < .001$) and a large effect (Cohen's $d = 2.43$). Decomposition showed the greatest improvement among the CT indicators (N-Gain = 0.699). The adaptive website significantly improved students' CT skills through competency-based progressive scaffolding support. Future studies should involve broader samples, longer interventions, and additional learning outcomes.

How to cite:
Masduki, W. A. et al., (2026). The effect of an adaptive scaffolding-based learning website on students' computational thinking skills. *Jurnal Inovasi Teknologi Pendidikan*, *13*(2), 254-263. https://doi.org/10.21831/jitp.v13i2.99406

INTRODUCTION

As digital technology continues to expand, Informatics education is increasingly expected to develop more than students' conceptual understanding, including their systematic reasoning, problem-solving abilities, and computational literacy (Kafai & Proctor, 2022; Palop et al., 2025). Within this broader educational context, Computational Thinking (CT) is particularly important because it enables learners to formulate problems and construct solutions using computational processes that are applicable across learning contexts (Wing, 2006; Ocampo et al., 2024). These processes encompass algorithmic thinking, decomposition, abstraction, and pattern recognition, through which learners can break problems into smaller components, identify recurring patterns, distinguish relevant information, and

organize solution steps in a logical sequence (Anggraini et al., 2025; Ekayana et al., 2025; Pirzado et al., 2025).

The growing need for CT development is closely related to the demands of digital and Informatics learning, in which students are expected to address data-, algorithm-, and technology-related problems both independently and collaboratively (Connolly et al., 2021; Kafai & Proctor, 2022). Evidence from previous studies suggests that students can achieve better CT and learning outcomes when interactive learning media are used instead of conventional instruction (Ekayana et al., 2025). In a quasi-experimental study involving 112 students, the authors reported a significant difference between groups ($t = 6.474$, $p < .001$). The experimental group increased from 41.64 to 79.71 and achieved an N-Gain of 0.65, whereas the control group recorded an N-Gain of 0.46.

AI-based interactive digital games have also been associated with CT development, particularly through learning activities that engage students in analysis, abstraction, and the construction of problem-solving strategies (Anggraini et al., 2025). Anggraini et al., (2025) reported a significant positive relationship between AI-based interactive digital game development and CT ($r = 0.407$, $p = .001$), with the model accounting for 30% of the variance in students' CT ($R^2 = 0.300$). A similar potential has been observed in web-based learning for supporting CT development. In the study by Selano et al., (2024), students' CT scores increased from 73.6 to 97.3 after using a web-based e-module integrated with Project-Based Learning, producing a high N-Gain of 0.898. Taken together, these findings suggest that technology-based learning can effectively support CT when learning activities are designed around interaction, contextual learning, and problem solving (Selano et al., 2024; Salwa et al., 2024).

Despite these positive findings, strengthening CT in classroom learning remains challenging. Because students begin learning with different levels of prior ability, the difficulty of a task may not always correspond to their readiness, while feedback may also lack a sufficiently gradual progression (El-Sabagh, 2021; Ocampo et al., 2024). These differences can leave some students struggling with problem solving, whereas others may need more demanding tasks to further develop their thinking skills (Sayed et al., 2023; Maryono et al., 2025). Adaptive learning environments can respond to differences in learner characteristics and performance, but the specific form and degree of that adaptation depend on the learning context. In existing applications, learner characteristics have been used to guide content presentation, exercise navigation, and feedback in adaptive e-learning, whereas CT-oriented scaffolding has been applied to assist students during problem solving (Sayed et al., 2023; Shin et al., 2025). What remains less certain is whether students' initial CT competence, differentiated task difficulty, and progressive scaffolding can be brought together within the same learning process. This issue is particularly relevant to Informatics learning, where topics such as algorithms, programming, and digital problem solving require support that responds systematically and adaptively to students' performance (Oksila et al., 2025; Shin et al., 2025).

A range of instructional approaches has been explored to strengthen CT, including mobile learning, web-based e-modules, game-based learning, adaptive e-learning, and instructional scaffolding (Connolly et al., 2021; Selano et al., 2024; Tikva & Tambouris, 2023). The relevance of website-based media lies in their ability to combine flexible access with organized learning materials, interactive activities, and automatic recording of students' learning activities (Oksila et al., 2025; Salwa et al., 2024). By responding to students' characteristics or performance, adaptive e-learning can modify the content, level of difficulty, and learning activities presented by the system (El-Sabagh, 2021; Sayed et al., 2023). For complex learning tasks, scaffolding provides progressive assistance that can help manage cognitive load while supporting students' learning independence (Doo et al., 2020; Peng et al., 2022). Yet, relatively little research has brought these functions together in one CT-oriented learning environment where students' initial competence is identified first and then used to determine both task difficulty and scaffolding support.

To address this gap, the present study employed a learning website that incorporates adaptive scaffolding. Within the website, students are assigned to adaptive learning levels and receive progressive assistance while working on CT case studies. Operationally, the adaptive scaffolding mechanism determines students' learning levels from their pretest scores and delivers tiered hints as they work through the case studies. The pretest serves as the initial cognitive map of students' CT competence; the resulting information is then used to assign the appropriate learning level and determine the scaffolding support provided afterward. The approach was selected because, in a digital learning environment,

adaptive scaffolding can personalize support, vary the assistance provided according to students' needs, and strengthen problem-solving effectiveness (Munshi et al., 2022; Triana-Vera & López-Vargas, 2025). Evidence also suggests that scaffolding can contribute to CT development, particularly in programming tasks, problem-solving activities, and game- or simulation-based learning (Shin et al., 2025; Tikva & Tambouris, 2023).

Although interactive media, adaptive e-learning, and scaffolding have been examined in previous studies, limited evidence is available on their integration through a learning website that uses pretest-based initial cognitive mapping, CT case studies, and tiered hints, particularly for Grade X senior high school Informatics learning. Earlier studies have largely examined mobile learning, digital games, e-modules, or general adaptive e-learning. Although these approaches have produced positive findings, their emphasis has generally been placed on overall learning outcomes, personalization, or scaffolding rather than on linking students' initial CT competence to differentiated CT tasks and tiered support. For example, interactive mobile learning achieved an N-Gain of 0.65 for CT (Ekayana et al., 2025), while a web-based PjBL e-module achieved an N-Gain of 0.898 (Selano et al., 2024). Benefits have also been reported for adaptive personalized learning and CT-related scaffolding, particularly in learning effectiveness and problem-solving performance (Sayed et al., 2023; Shin et al., 2025). However, empirical testing of a website that combines adaptive levels, CT case studies, and tiered hints through a quasi-experimental design remains limited (Anggraini et al., 2025; Maryono et al., 2025). Accordingly, empirical evidence is needed to determine whether an adaptive scaffolding-based learning website can effectively improve students' CT skills.

Building on this background, the study examines whether the use of an adaptive scaffolding-based learning website affects the Computational Thinking skills of Grade X students in Informatics. The learning sequence implemented through the website begins with a pretest, followed by adaptive level determination, material presentation, level-based case studies, tiered hints, and a posttest, and concludes with a summary of learning outcomes. Four indicators were used to assess CT skills in this study: decomposition, pattern recognition, abstraction, and algorithmic thinking. At the theoretical level, the study extends empirical evidence concerning how initial cognitive mapping can be integrated with adaptive scaffolding in CT learning. From a practical perspective, the study offers a web-based learning design in which students' initial competence is linked to differentiated CT case studies, tiered hints, exercises, and feedback.

METHOD

A quantitative quasi-experimental approach was adopted in the present study, using a nonequivalent control group pretest-posttest design. Because the participants were drawn from existing classes, individual randomization could not be conducted; therefore, the nonequivalent group design was selected. The research design is presented in Table 1.

Table 1. Quasi-Experimental Design

No.	Group	Pretest	Intervention	Posttest
1	Control	O1	X1	O2
2	Experimental	O3	X2	O4

The sample comprised 72 students from two classes, each consisting of 36 students; one class served as the experimental group and the other as the control group. The use of cluster sampling reflected the selection of intact classes that were already established at the school. Instruction in the experimental class was delivered through the adaptive scaffolding-based learning website, whereas the control class followed conventional instruction. For the control class, conventional instruction involved teacher explanations, classroom discussions, practice questions, and assignments, with no adaptive website or tiered hints.

Students engaged with the material through problem-solving activities and case studies in which they were required to identify problems, recognize patterns, determine relevant information, and organize solution steps logically. The intervention was implemented across three meetings, each lasting 2 × 45 minutes. Students in the experimental class used the adaptive scaffolding-based learning website,

whereas the control class received conventional instruction covering the same material and learning objectives.

CT development through the website followed a structured sequence beginning with a pretest and adaptive level determination, followed by material presentation, case-study completion, hint provision, and a posttest, and ending with a summary of learning outcomes. Students' pretest scores served as the basis for determining their adaptive learning levels. A pretest score below 50 placed a student in the basic level, scores from 50–75 corresponded to the intermediate level, and scores above 75 indicated the advanced level. Three levels of hints were incorporated into each case study, allowing support to become progressively available when students encountered difficulties in problem solving. Students' initial abilities determined the level of learning difficulty through the adaptive mechanism, while scaffolding supplied progressive assistance throughout problem solving (Kafai & Proctor, 2022; Shute et al., 2017). The criteria used to determine the adaptive levels are presented in Table 2.

Table 2. Adaptive Level Criteria

No.	Adaptive Level	Pretest Score	Bloom Taxonomy	Cognitive Category
1	Basic	< 50	C2–C3	LOTS–MOTS
2	Intermediate	50–75	C4	Initial HOTS
3	Advanced	> 75	C5	HOTS

The research instrument was structured around four CT indicators: decomposition, abstraction, pattern recognition, and algorithmic thinking. Together, these indicators represent systematic processes used in problem solving (Brennan & Resnick, 2012; Wing, 2006). The definition of each Computational Thinking indicator is presented in Table 3.

Table 3. Computational Thinking Indicators

No.	Indicator	Explanation
1	Decomposition	The ability to divide complex problems into simpler components
2	Pattern Recognition	The ability to recognize patterns, regularities, or similarities within a problem
3	Abstraction	The ability to identify relevant information while excluding irrelevant details
4	Algorithmic Thinking	The ability to organize problem-solving steps in a logical and systematic sequence

The study employed three forms of learning instruments: a pretest, a posttest, and case studies. Each pretest and posttest contained 20 multiple-choice items with five response options, with the items developed according to the four CT indicators. Twelve case studies were distributed across the three adaptive levels, with hints available to support students as they progressed through each case. The website also recorded students' learning levels, completion time, hint usage, learning progress, and final scores. Students and teachers used these records mainly to monitor learning activities; the log data were not included in the inferential statistical analysis. Effectiveness was determined from students' pretest and posttest CT scores, followed by N-Gain analysis, normality and homogeneity testing, an independent-samples t-test, and Cohen's d calculation. The details of the research instruments are presented in Table 4.

Table 4. Research Instruments

No.	CT Element	Pretest	Posttest	Case Study	Hint
1	Decomposition	5 items	5 items	3 cases	9 hints
2	Pattern Recognition	5 items	5 items	3 cases	9 hints
3	Abstraction	5 items	5 items	3 cases	9 hints
4	Algorithmic Thinking	5 items	5 items	3 cases	9 hints
Total		**20 items**	**20 items**	**12 cases**	**36 hints**

The website media, learning materials, and Computational Thinking Skills test instrument were subjected to expert validation. For the materials and CT instrument, feasibility percentages and Aiken's V were used to evaluate feasibility and content validity, whereas media validation relied on feasibility percentages because only one validator was involved. The pretest and posttest were also trialed with 36 Grade X students to examine item validity, reliability, difficulty, and discrimination. Pearson Product-

Moment correlation was applied to assess item validity, while Cronbach's Alpha was used to evaluate reliability.

The trial indicated that all 20 pretest items and 20 posttest items met the validity criteria, with the obtained r-value exceeding the r-table value of 0.329. The resulting Cronbach's Alpha of 0.842 indicated that the instrument had high reliability. Analysis of item difficulty and discrimination likewise indicated that the items were suitable for use; several items required minor revisions, but these changes did not alter the main question indicators.

Changes in students' Computational Thinking Skills were quantified using N-Gain. N-Gain was obtained using the following calculation formula.

$$N - Gain = \frac{Posttest - Pretest}{Maksimum\ Skor - Pretest}$$

N-Gain scores were interpreted using three categories: low for $g < 0.30$, moderate for $0.30 \leq g < 0.70$, and high for $g \geq 0.70$. Prior to hypothesis testing, normality was checked with the Shapiro-Wilk test and variance homogeneity with Levene's test using the N-Gain data. As both assumptions were satisfied, the hypothesis was evaluated using an independent-samples t-test, with the interpretation based on the "Equal variances assumed" row. Treatment magnitude was subsequently estimated using Cohen's d. For interpretation, Cohen's d values of 0.20, 0.50, and 0.80 or above represented small, medium, and large effects, respectively.

RESULTS AND DISCUSSION

Results

Two classes participated in the study, comprising an experimental class and a control class. Instruction in the experimental class was delivered through the adaptive scaffolding-based website, whereas the control class followed conventional instruction. Before implementation, the instruments and learning devices underwent expert validation to establish their feasibility.

Three aspects were subjected to validation: media, learning materials, and the Computational Thinking Skills test instrument. The validation results were analyzed using feasibility percentages. Specifically for the validation of the material and test instrument, the analysis was also supported by Aiken's V index because it involved more than one validator. A summary of the validation results is presented in Table 5.

Table 5. Expert Validation Results

No.	Validation Aspect	Feasibility Percentage	Aiken's V	Category
1	Media expert	89.29%	-	Very Feasible
2	Material expert	98.61%	0.981	Very Feasible and Very Valid
3	Computational Thinking Skills instrument	97.60%	0.967	Very Feasible and Very Valid

Table 5 shows feasibility percentages of 89.29% for the media, 98.61% for the materials, and 97.60% for the Computational Thinking Skills instrument. Media expert validation was conducted by one validator; therefore, the analysis focused on the feasibility percentage and did not use Aiken's V. The corresponding Aiken's V values were 0.981 for the materials and 0.967 for the Computational Thinking Skills test instrument, both falling within the very valid category. Accordingly, the website, learning materials, and test instrument met the feasibility and validity requirements for use in the study.

The pretest and posttest instruments were also trialed with 36 Grade X students before their use in the main study. All 20 pretest items and 20 posttest items met the validity criteria. The instrument produced a Cronbach's Alpha of 0.842, indicating high reliability. Analysis of item difficulty and discrimination further showed that the items were suitable for use, although several items required minor revisions that did not alter the main question indicators.

After the learning devices were declared feasible, the learning process was implemented in the experimental and control classes. Both classes were given a pretest before the treatment and a posttest

after the treatment. Table 6 summarizes the pretest, posttest, difference, and N-Gain results for the two groups.

Table 6. Descriptive Summary of Computational Thinking Skills Results

No.	Class	N	Mean Pre	Mean Post	Mean Difference	Mean N-Gain	Category
1	Control	36	55.28	71.39	16.11	0.36	Moderate
2	Experimental	36	55.14	81.11	25.97	0.58	Moderate

The pretest results indicated comparable starting levels between the two groups, with mean scores of 55.28 for the control class and 55.14 for the experimental class (Table 6). After the intervention, the mean posttest score increased to 71.39 in the control group and 81.11 in the experimental group. These changes corresponded to mean gains of 16.11 and 25.97 points, respectively. A similar difference was observed in N-Gain, with mean values of 0.36 for the control group and 0.58 for the experimental group. Although both groups remained in the moderate category, the experimental group showed the greater improvement in CT Skills.

The improvement in Computational Thinking Skills was further examined at the indicator level by comparing pretest, posttest, gain, and N-Gain scores for decomposition, pattern recognition, abstraction, and algorithmic thinking. The results are summarized in Table 7.

Table 7. Computational Thinking Skills by Indicator

CT Indicator	Control Pretest	Control Posttest	Gain	Control N-Gain	Experiment Pretest	Experiment Posttest	Gain	Experiment N-Gain
Decomposition	52.78	69.44	16.67	0.353	53.89	86.11	32.22	0.699
Pattern Recognition	53.89	69.44	15.56	0.337	52.22	79.44	27.22	0.570
Abstraction	51.67	72.78	21.11	0.437	58.89	83.89	25.00	0.608
Algorithmic Thinking	62.78	73.89	11.11	0.299	55.56	75.00	19.44	0.438

Across all four CT indicators, the experimental group recorded greater improvement than the control group (Table 7). For the experimental group, decomposition produced the highest N-Gain at 0.699 after increasing from 53.89 to 86.11, followed by abstraction at 0.608, pattern recognition at 0.570, and algorithmic thinking at 0.438. The corresponding N-Gain values in the control group were 0.353, 0.337, 0.437, and 0.299, respectively. Taken together, these results show that the experimental group improved more across each CT indicator when learning with the adaptive scaffolding-based website.

Decomposition produced the largest gain among the four indicators in the experimental group: 32.22 points versus 16.67 points in the control group. This difference identifies decomposition as the indicator showing the strongest response to the adaptive scaffolding intervention. One possible explanation is that the learning activities and tiered hints guided students to approach complex problems by separating them into smaller, manageable components that corresponded to their initial learning levels.

The assumptions required for hypothesis testing were examined before the main statistical test was conducted, beginning with normality and homogeneity. Because each class contained 36 students, normality was assessed using the Shapiro-Wilk test. The normality test results are shown in Table 8.

Table 8. Normality Analysis Results for N-Gain Scores

No.	Class	Data	Shapiro-Wilk Sig.	Description
1	Control	N-Gain	0.268	Normal
2	Experimental	N-Gain	0.182	Normal

The Shapiro-Wilk results in Table 8 yielded significance values of 0.268 for the control class and 0.182 for the experimental class. Since both values were above 0.05, the N-Gain data in both groups met the normality assumption.

Variance homogeneity was then examined to determine whether the N-Gain distributions of the two classes had equivalent variances. The results of the homogeneity test are presented in Table 9.

Table 9. Homogeneity Analysis Results for N-Gain Scores

Data	Levene's Statistic	df1	df2	Sig.	Description
N-Gain	0.077	1	70	0.782	Homogeneous

As reported in Table 9, Levene's test produced a statistic of 0.077 with a significance value of 0.782. Since the significance value exceeded 0.05, the N-Gain variances were considered homogeneous across the two groups. Since the N-Gain data met the assumptions of normality and homogeneity, hypothesis testing was subsequently carried out using the independent-samples t-test, with reference to the "Equal variances assumed" row. The hypothesis test results are shown in Table 10.

Table 10. Independent Samples t-Test Results

Data	Statistical Test	t	df	Sig. (2-tailed)	Mean Difference	Description
N-Gain	Equal Variances Assumed	-10.214	70	0.000	-0.217083	Significant

The comparison of N-Gain scores showed a statistically significant difference between the control and experimental groups ($t(70) = -10.214$, $p < .001$; Table 10). The experimental group obtained the higher mean N-Gain, 0.58, compared with 0.36 in the control group, resulting in a 0.217-point difference in favor of the experimental group. These results indicate greater improvement for students learning under the adaptive scaffolding-based condition than for those receiving conventional instruction.

The magnitude of the intervention effect was quantified using Cohen's d, with the result presented in Table 11.

Table 11. Effect Size Results

Data	Control Mean	Experimental Mean	Pooled SD	Cohen's d	Category
N-Gain	0.36	0.58	0.09016	2.43	Large

The analysis produced a Cohen's d value of 2.43, which falls within the large-effect category because it exceeds 0.80. Thus, the adaptive scaffolding-based learning website was associated with a large effect on students' Computational Thinking Skills. Overall, the experimental group showed greater improvement than the control group, while the website was considered feasible and effective for supporting CT learning.

Discussion

The results provide evidence that the adaptive scaffolding-based learning website was feasible and effective for CT instruction. Expert validation classified the media, learning materials, and test instrument as very feasible, indicating that the learning components satisfied the required criteria before implementation. The experimental class also obtained a higher mean N-Gain (0.58) than the control class (0.36). The difference between the two groups was statistically significant ($t(70) = -10.214$, $p < .001$), and the Cohen's d value of 2.43 indicated a large effect. These results indicate that the improvement in CT Skills was greater among students who used the adaptive scaffolding-based website than among those who received conventional instruction.

The greater improvement may be associated with the combination of adaptive learning and progressive scaffolding used in the intervention. Students first received learning materials and case studies according to their initial levels, while tiered hints and feedback were provided during the problem-solving activities rather than giving the same support to all students. Through this sequence, the learning activities addressed the four CT indicators: decomposition involved breaking complex problems into smaller parts, pattern recognition was supported through exercises and case studies, abstraction focused on identifying relevant information, and algorithmic thinking involved arranging solution steps logically.

The indicator-level results showed the largest improvement for decomposition. In the experimental group, decomposition reached an N-Gain of 0.699, compared with 0.353 in the control group, making it the indicator with the highest gain. This result may be related to the way the intervention guided students to separate complex problems into smaller and more manageable components. The initial cognitive mapping based on pretest performance may have helped align case

difficulty with students' readiness, while the tiered hints offered more specific assistance when students encountered difficulties.

This sequence may have helped students form a clearer representation of a problem before proceeding to pattern recognition, abstraction, and algorithmic solution development. The findings therefore suggest that the adaptive scaffolding-based website may support not only overall CT improvement but also specific CT processes, with decomposition showing the greatest improvement in this study. This interpretation is consistent with computational thinking as a problem-solving process that involves problem formulation, information representation, abstraction, and the development of solution procedures (Brennan & Resnick, 2012; Shute et al., 2017; Wing, 2006). It also corresponds with findings reported by Contrino et al., (2024), Peng et al., (2022), and Shin et al., (2025), who found that adaptive scaffolding can assist students with complex tasks, improve learning performance, and reduce cognitive load.

The present findings are also in line with earlier research on technology-supported CT learning. Ekayana et al., (2025), for example, reported improvements in computational thinking and learning achievement through interactive mobile learning compared with conventional instruction. Related findings from Anggraini et al., (2025) and Buchori et al., (2025) showed that interactive digital technology can support CT-related indicators through learning activities that are active, contextualized, and structured. Yanto et al., (2023) found that Google Sites-based learning media were feasible for Informatics learning in vocational high schools. At the same time, research on adaptive e-learning and scaffolding has highlighted benefits related to personalization, student engagement, and problem-solving skills (Doo et al., 2020; El-Sabagh, 2021; Sayed et al., 2023; Triana-Vera & López-Vargas, 2025).

A major contribution of this study is the integration of adaptive level determination, CT-based case studies, tiered hints, exercises, and feedback within a single adaptive scaffolding-based learning website. Unlike approaches that mainly use mobile learning, e-modules, Google Sites, or adaptive e-learning for content delivery or general personalization, the website in this study uses students' initial abilities to guide the progression of CT learning and support. The findings should also be considered in light of the study limitations. The research involved only two classes, and effectiveness was evaluated mainly through pretest and posttest results. Future studies could extend this work by involving larger samples, using longer learning periods, and examining additional outcomes such as learning motivation, student engagement, long-term retention, and students' activity logs.

Overall, the findings suggest that the effectiveness of the adaptive scaffolding-based website is related to how personalized learning, progressive assistance, problem-based exercises, and feedback are integrated within one learning environment. This design enables support to respond to students' initial abilities while remaining available when difficulties occur in pattern recognition, decomposition, abstraction, and algorithmic thinking. In this respect, the study adds empirical evidence to technology-based CT learning and provides an Informatics learning design that is more adaptive, structured, and focused on CT development.

CONCLUSION

The findings indicate that the adaptive scaffolding-based learning website was feasible and effective for use in Informatics CT learning. Expert validation classified the website, learning materials, and test instrument as very feasible. The experimental class showed greater improvement than the control class, as reflected in the mean N-Gain scores of 0.58 and 0.36, respectively. Among the four CT indicators, decomposition showed the highest gain in the experimental group (N-Gain = 0.699), suggesting that the intervention may have provided stronger support when students were required to divide complex problems into smaller components.

Statistical analysis confirmed a significant difference in improvement between the two classes ($t(70) = -10.214$, $p < .001$). The effect size was large, with a Cohen's d of 2.43. These findings suggest that the integration of adaptive levels, CT case studies, tiered hints, exercises, and feedback can support the development of CT within the learning process. Scientifically, the study contributes to website-based Informatics learning by showing how adaptive mechanisms and scaffolding can be integrated into a single digital learning environment.

These findings should be interpreted in light of several limitations. The study involved a limited number of participants, used a relatively short treatment period, and relied on pretest-posttest measurement to assess the outcomes. Future studies could strengthen the evidence by involving larger and more diverse participant groups, extending the duration of the intervention, and applying the approach to a broader range of Informatics topics. Further research could also examine additional outcomes, including learning motivation, student engagement, learning independence, and retention of learning outcomes.

REFERENCES

Anggraini, D. N., Komalasari, K., Sopianingsih, P., Insani, N. N., & Sudrajat, A. (2025). AI-based interactive digital game development in social studies learning to enhance students' computational thinking. *Jurnal Inovasi Teknologi Pendidikan*, *12*(4), 468–479. https://doi.org/10.21831/jitp.v12i4.89738

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *Proceedings of the 2012 Annual Meeting of the American Educational Research Association*, 1–25. https://scratched.gse.harvard.edu/ct/files/AERA2012.pdf

Buchori, A., Rahmadhani, T. A., Rozzaqi, A. R., & Khoiri, N. (2025). Developing web-based learning media for enhancing digital literacy in computer networking. *Indonesian Journal of Educational Development (IJED)*, *6*(3), 737–751. https://doi.org/10.59672/ijed.v6i3.5361

Connolly, C., Hijón-Neira, R., & Grádaigh, S. (2021). Mobile learning to support computational thinking in initial teacher education: A case study. *International Journal of Mobile and Blended Learning, 13*(1), 49–62. https://doi.org/10.4018/IJMBL.2021010104

Contrino, M. F., Reyes-Millán, M., Vázquez-Villegas, P., & Membrillo-Hernández, J. (2024). Using an adaptive learning tool to improve student performance and satisfaction in online and face-to-face education for a more personalized approach. *Smart Learning Environments*, *11*(6), 1-24. https://doi.org/10.1186/s40561-024-00292-y

Doo, M. Y., Bonk, C. J., & Heo, H. (2020). A meta-analysis of scaffolding effects in online learning in higher education. *The International Review of Research in Open and Distributed Learning*, *21*(3), 60-80. https://doi.org/10.19173/irrodl.v21i3.4638

Ekayana, A. A. G., Putra, D. M. D. U., & Sudatha, I. G. W. (2025). Interactive mobile learning to improve computational thinking and achievement in digital systems courses. *Jurnal Inovasi Teknologi Pendidikan, 12*(4), 444–454. https://doi.org/10.21831/jitp.v12i4.89321

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(53), 1-24. https://doi.org/10.1186/s41239-021-00289-4

Kafai, Y. B., & Proctor, C. (2022). A Revaluation of computational thinking in K–12 education: Moving toward computational literacies. *Educational Researcher*, *51*(2), 146–151. https://doi.org/10.3102/0013189X211057904

Maryono, D., Sajidan, Akhyar, M., Sarwanto, Wicaksono, B. T., & Prakisya, N. P. T. (2025). NgodingSeru.com: An adaptive e-learning system with gamification to enhance programming problem-solving skills for vocational high school students. *Discover Education*, *4*(157), 1-16. https://doi.org/10.1007/s44217-025-00581-9

Munshi, A., Biswas, G., Baker, R., Ocumpaugh, J., Hutt, S., & Paquette, L. (2022). Analyzing adaptive scaffolds that help students develop self-regulated learning behaviors. *Journal of Computer Assisted Learning*, *39*(2), 351–368. http://doi.org/10.1111/jcal.12761

Ocampo, L. M., Corrales-Álvarez, M., Cardona-Torres, S. A., & Zapata-Cáceres, M. (2024). Systematic review of instruments to assess computational thinking in early years of schooling. *Education Sciences*, *14*(10), 1-25. https://doi.org/10.3390/educsci14101124

Oksila, D., Giatman, Irfan, D., & Alawyah, K. (2025). Validity and effectiveness of e-module-based learning media in informatics subjects. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 431–440. https://doi.org/10.29303/jppipa.v11i2.9861

Palop, B., Díaz, I., Rodríguez-Muñiz, L. J., & Santaengracia, J. J. (2025). Redefining computational thinking: A holistic framework and its implications for K-12 education. *Education and Information Technologies*, *30*(10), 13385–13410. https://doi.org/10.1007/s10639-024-13297-4

Peng, J., Yuan, B., Sun, M., Jiang, M., & Wang, M. (2022). Computer-based scaffolding for sustainable project-based learning: Impact on high- and low-achieving students. *Sustainability (Switzerland)*, *14*(19), 1-24. https://doi.org/10.3390/su141912907

Pirzado, F. A., Ahmed, A., Hussain, S., Ibarra-Vázquez, G., & Terashima-Marin, H. (2025). Assessing computational thinking in engineering and computer science students: A multi-method approach. *Education Sciences*, *15*(3), 1-26. https://doi.org/10.3390/educsci15030344

Salwa, K. A., Bachri, S., & Kristanto, A. (2024). Development of interactive website learning media for grade X high school students. *Jurnal Akademika*, *13*(02), 186–203. https://doi.org/10.34005/akademika.v13i02.4309

Sayed, W. S., Noeman, A. M., Abdellatif, A., Abdelrazek, M., Badawy, M. G., Hamed, A., & El-Tantawy, S. (2023). AI-based adaptive personalized content presentation and exercises navigation for an effective and engaging e-learning platform. *Multimedia Tools and Applications*, *82*(3), 3303–3333. https://doi.org/10.1007/s11042-022-13076-8

Selano, Y. P., Sutimin, L. A., & Sumaryati, S. (2024). Web-based e-module with a project based learning approach to improve computational thinking skills of high school students. *Journal of Education Technology*, *8*(4), 763–775. https://doi.org/10.23887/jet.v8i4.85248

Shin, Y., Jung, J., Choi, S., & Jung, B. (2025). The influence of scaffolding for computational thinking on cognitive load and problem-solving skills in collaborative programming. *Education and Information Technologies*, *30*(1), 583–606. https://doi.org/10.1007/s10639-024-13104-0

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

Tikva, C., & Tambouris, E. (2023). The effect of scaffolding programming games and attitudes towards programming on the development of computational thinking. *Education and Information Technologies*, *28*(6), 6845–6867. https://doi.org/10.1007/s10639-022-11465-y

Triana-Vera, S., & López-Vargas, O. (2025). Academic self-efficacy, online self-efficacy, and fixed and faded scaffolding in computer-based learning environments. *Contemporary Educational Technology*, *17*(2), 1-17. https://doi.org/10.30935/cedtech/16030

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35. https://doi.org/10.1145/1118178.1118215

Yanto, R., Waskito, W., Effendi, h., & purwanto, w. (2023). development of web-based learning media using Google Sites in vocational high school informatics subjects. *Journal of Vocational Education Studies*, *6*(1), 11–24. https://doi.org/10.12928/joves.v6i1.8027