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Enhancing Human Evolution Literacy through PraksaraVerse: A Gamified Science Learning Innovation Supporting Sustainable Development Goals (SDGs)

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ABSTRACT

This study developed and evaluated PraksaraVerse, a gamified interactive learning application designed to enhance students' literacy in human evolution as part of science education. Using the Luther Research and Development model, the application was designed to incorporate multimedia content, 3D simulations, quizzes, and augmented reality, fostering immersive and contextual learning. A quasi-experimental design was applied to 205 eleventh-grade students from three high schools in Yogyakarta, Indonesia. Data were collected using validated comprehension tests and perception questionnaires. The results revealed a statistically significant improvement in the Beta group, which used the refined version of the application. Students reported high engagement, improved understanding, and positive user experience. The integration of scientific content, technological features, and visual narratives aligns with Sustainable Development Goals (SDGs) by promoting inclusive, equitable, and quality education through digital innovation. PraksaraVerse demonstrates the potential of educational technology to address abstract scientific concepts while fostering active learning in secondary education.

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1. INTRODUCTION

Understanding human evolution and prehistoric life is a key component of science and history education [1-3], especially at the secondary school level. This topic introduces students not only to biological and anthropological aspects of human origins but also to the broader scientific understanding of Earth's history and life dynamics over time [4, 5]. However, in practice, this material is often difficult for students to grasp due to its abstract nature, limited teaching resources, and a lack of engaging and interactive media. Teachers also face challenges in delivering this content effectively, particularly in contexts where evolution remains a sensitive or controversial subject [5, 6].

With the rapid advancement of educational technology and the emergence of digital-native learners, there is a growing need for adaptive and interactive learning solutions. Studies show that digital media and gamification can significantly enhance motivation, cognitive engagement, and learning outcomes in science education [7, 8]. Many reports regarding gamification have been well-documented [9-15].

Particularly in complex and abstract subjects such as evolutionary biology, the integration of visual simulations, narrative storytelling, and interactive features can foster deeper conceptual understanding [16-23]. In the Indonesian context, the national education roadmap (2020–2035) emphasizes the need to strengthen digital-based learning and 21st-century skills in schools [24]. This policy push highlights the importance of aligning learning innovation with both curricular needs and students' digital literacy.

In response to these challenges and opportunities, *PraksaraVerse* was developed as a web- and mobile-based interactive learning application that uses gamification and multimedia to teach concepts of human evolution. It integrates scientific content, historical narratives, 3D models, augmented reality (AR), and quizzes into a cohesive and engaging learning experience. The app is built using a constructivist approach, encouraging students to actively explore evolutionary topics through simulation, reflection, and inquiry [25-28]. Previous studies have explored interactive media in subjects such as chemistry and general science, but few have focused specifically on integrating historical science content like human evolution within a gamified digital platform.

The purpose of this study is to design, implement, and evaluate the effectiveness of *PraksaraVerse* in improving students' understanding of human evolution and prehistoric life. The novelty of this research lies in its interdisciplinary integration of evolutionary science, archaeology, and gamified technology within a culturally contextualized and curriculum-aligned educational tool. By transforming abstract evolutionary concepts into immersive and student-centered experiences, *PraksaraVerse* supports Sustainable Development Goal 4 (Quality Education) by promoting inclusive, equitable, and high-quality science education through digital innovation.

2. LITERATURE REVIEW

Education serves as a fundamental pillar in shaping the cognitive, emotional, and social development of individuals and societies. That is the main reason many researchers developed the process in education as well as teaching and learning (**Table 1**). In the context of the 21st century, education is not only expected to transmit knowledge but also to cultivate critical thinking, scientific reasoning, digital literacy, and lifelong learning habits. The advancement of science and technology, along with global challenges such as climate change, health crises, and social inequality, demands an educational model that is adaptive, inclusive,

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and innovation-driven. Quality education has thus been enshrined as Sustainable Development Goal 4 (SDG 4) by the United Nations, emphasizing the need for equitable access, effective learning outcomes, and integration of digital resources to enhance the teaching and learning process. Research consistently highlights that educational quality can be significantly improved through well-designed learning environments, innovative pedagogical approaches, and evidence-based technological integration [7, 24]. Within this context, the development of interactive learning media plays a crucial role in responding to evolving educational demands.

Table 1. Previous studies on education.

No	Title	Reference
1	Bibliometric analysis using VOSviewer with Publish or Perish of computational thinking and mathematical thinking in elementary school	[29]
2	Students' virtual classroom experiences in the post-COVID-19 era	[30]
3	Effect of two instructional strategies on students' achievement in selected abstract concepts in biology	[31]
4	Evaluation of robotics class in a private school in the Philippines	[32]
5	Problem-based learning (PBL) learning model for increasing learning motivation in chemistry subject: Literature review with bibliometric analysis	[33]
6	Development, validity, and acceptability of android-based applications in ecology: A technology acceptance model (TAM) approach	[34]
7	Improving students' critical thinking through blended learning media learning game Word Wall	[35]
8	The future of teaching: Artificial intelligence (AI) and artificial general intelligence (AGI) for smarter, adaptive, and data-driven educator training	[36]
9	Evolution and advancements from neural network to deep learning	[37]
10	Analyzing junior high school students' cognitive load in a science subject: A case study	[38]
11	The ethical and educational implications of greenwashing in corporate sustainability practices	[39]
12	Cultivating the pedagogical competence of pre-service science teachers through microteaching	[40]
13	Bibliometric analysis using VOSviewer with Publish or Perish of CEFR-based comparison of English language teaching models for communication	[41]
14	The emergence of new technologies in metalwork/automobile industries: Issues, challenges and opportunities in emanating from for delivery of technical education on a pandemic era	[42]
15	Student teaching and instructional materials in the 21st-century classroom: A literature review	[43]
16	The impact of project-based learning (PjBL) on students' motivation and learning outcomes: A literature review	[44]
17	Context evaluation in nanotechnology courses: A context, input, process, and product (CIPP) model perspective	[45]
18	An investigation of factors that motivate academics to conduct research and research productivity in Lao Public Universities	[46]
19	Preparing future geography teachers through problem-based learning technology: A short review	[47]
20	Perception of early childhood education lecturers on the use of virtual learning	[48]
21	The effectiveness of blended education in educational institutions	[49]
22	The impact of phonetic rhythmicity on speech and communication skills of elementary students with special needs	[50]

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Table 1 (Continue). Previous studies on education.

No	Title	Reference
23	Examining the impact of block-based visual programming in programming education: A systematic review	[51]
24	Effect of cross-over learning on pupils' academic performance in civic education	[52]
25	Emerging technologies for sustainable universities and colleges: A meta-synthesis	[53]
26	Assessment of instructional material relevance and availability for biology education	[54]

2.1. Interactive Learning Media

Previous studies [55] concluded that digital educational games significantly improve students' academic achievement in science subjects compared to traditional methods. These results are particularly relevant because *PraksaraVerse* is designed to help understand the concept of human evolution, which is part of the Science material with interactive gamification methods.

Global trends also show a rapid increase in game-based learning research between 2015–2024 based on Scopus and Web of Science data. Recent bibliometric studies show that Clustering Scopus includes the themes of game-based learning and serious games, as well as a human-centred design approach [56]. These findings support the idea that educational platforms like *PraksaraVerse* are on a highly developed and recognized research path in the context of educational technology.

According to the literature [28], educational game media design needs to pay attention to user engagement, scaffolding, and motivational elements to support learning performance. In the context *of the PraksaraVerse*, this means that the game should provide an adventure map (scaffold roaming) that guides the physical exploration of evolutionary concepts, quiz buttons, and score/life/time indicators that provide instant and motivating feedback, and an educational modern visual design without compromising on the substance of prehistoric science. Interactive media [27] indicates that MQI (multimedia quiz/instruction) is designed with scientific annotations to increase students' interest and activity in chemistry concepts. This underscores the need for *PraksaraVerse's design* to be interactive and based on an accurate representation of scientific concepts.

Meta-analysis of game-based learning in science education conducted [26, 59] concluded that offering simulation experiences and interactive sandboxes is more effective than nondigital approaches, as students can experience them concretely. DGBL (Digital Game-Based Learning) has proven to be more effective for science subjects than engineering or computer science alone, although *PraksaraVerse* contains technical engineering elements in the design of the game itself [26]. This reinforces that the focus on science-based human evolution is compatible with games as a learning medium.

Although *PraksaraVerse* is currently web-based and mobile without AR, AR studies in informal STEM (museums, science centers) reveal that interactive UX improves understanding of complex concepts such as evolution and fossils. Gamification and AR facilitate personalization and learning engagement. Interactive simulations such as PhET (physics/chemistry) successfully visualize abstract scientific concepts through hands-on manipulation (Nelson Gabbard, 2023; Setiawan & Phillipson, 2019). This design principle is relevant to be applied in *the PraksaraVerse* with elements of prehistoric exploration, for

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example: interactive maps, a visual timeline of evolution, and character exploration as a means of visualizing prehistoric science.

A Review [61] regarding mobile-AR serious games (MARSG), demonstrate the importance of pedagogical design based on constructivist learning theories and behaviorism, such as scaffolding and in-game reflection. Although *PraksaraVerse* is not AR, this pedagogical approach can be adopted: for example, inserting an interactive narrative describing the process of human evolution, with reflective questions and progressive feedback. RelicVR developed is an educational VR game that invites players to explore archaeological artifacts interactively. This approach increases the motivation and exploration of users towards illustrative historical stories. While not a direct model for gamified quizzes, this "active exploration and storytelling" approach could be a source of inspiration in *the PraksaraVerse* to build a human evolutionary adventure. The results of this literature review can be summarized as an overview in **Table 2** to make learning media effective and interactive.

Table 2. Technology-based interactive learning media.

Key Findings	Description	Reference
Motivation and Engagement	Game-based interactive media has been proven to increase students' motivation to learn compared to traditional methods.	[25, 26, 28]
The Effectiveness of Science	Game-based learning is more effective in science subjects than non-science disciplines, due to the use of simulations and scientific visualizations.	[26, 58]
Pedagogical Design	Scaffolding, instant feedback, and narrative exploration have been proven to support learning scientific and historical constructs.	[28, 59]

2.2. Learning Gamification

Gamification is the application of game design elements such as points, badges, leaderboards, feedback mechanics, challenges, avatars, and narratives in a non-game context to increase student motivation, engagement, and learning outcomes [60]. Recent metaanalysis and SLR studies show that gamification significantly improves student engagement, intrinsic motivation, as well as academic achievement, with moderate to high effects (Hedges' $g \approx 0.78$; $p < 0.05$) [61, 62].

Some researchers [63] conducted a systematic review of 90 gamification interventions in primary and secondary education; as a result, gamification supported student engagement (motivation, participation, and self-regulation), but emphasized the need for a more holistic approach to student engagement. Its effectiveness is not only limited to motivation, but also affects a positive attitude towards learning. Bibliometrics and literature reviews found that gamification research tends to be prevalent in STEM (science, technology, engineering, and mathematics), including interactive science, programming, and educational engineering [64].

Bibliometrics and literature reviews found that gamification research tends to be prevalent STEM (science, technology, engineering, and mathematics), including interactive science, programming, and educational engineering [64]. For science education, gamification has been shown to improve motivation and learning outcomes by aligning game element design with the learning goals of modern science students.

A meta-analysis of the 2008–2023 study (22 studies) showed that gamification had a moderate to high positive effect on students' academic achievement in a variety of subjects, including science and technology, as well as different levels of education [62]. This effect is consistent regardless of the variability of gamification design and learning context. Other meta-analysis studies also identified that the combination of elements such as points, badges,

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leaderboards, and feedback resulted in optimal effects on student achievement. While certain combinations, such as leaderboards alone or badges and levels, are sometimes less effective or even negative if they are not pedagogically integrated properly [62].

Not all gamification has a positive impact. Some studies warn of potential negative effects, such as decreased motivation after initial surprises, social comparison, cheating, or excessive focus on scores that interfere with the substantial learning process [66]. Therefore, an ethical and balanced design is needed, such as voluntariness, privacy, and non-manipulation.

2.3. Human Evolution in Learning

Human evolution is still often overlooked in school curricula, despite being a core component in understanding the science of evolution. Many countries do not include human evolution material in their textbooks or national standards. Human evolution education can increase students' evolutionary literacy and motivate the understanding of scientific concepts relevant to daily life [4]. Modern science learning emphasizes understanding the relationship between human evolution and the evolution of the universe and earth, such as the Big Bang theory, nucleosynthesis, and early geology. An interdisciplinary approach enriches the understanding of human evolution as a result of cosmological and geological processes [4, 67].

Textbooks and lesson plans often only mention in general chapters on the development of ancient human cultures, but details about the development of the Stone Age, the Paleolithic, the Neolithic, and the transition to the Metal Age are still poorly explored digitally. Evidence-based evaluation rubrics, such as artifacts, stone tools, and technological changes, are important for understanding human evolutionary literacy [6].

Learning about human evolution also requires an anthropological context as part of the information context. The use of archaeological and paleoanthropological sources as teaching materials is very important in providing information in context. For example, the activities of ancient human lifestyles, the use of fire or tools, and the migration of ancient humans to the archipelago. Literature research suggests presenting this material in an interactive and contextual format for students [5].

The identification of the species Homo erectus, Homo sapiens, Homo neanderthalensis, and their morphological characteristics are often an important part of the evolutionary educational literature. Literature evaluation shows that many curricula only mention without including the scientific context of genetic evolution, environmental adaptation, or geneculture coevolution [68]. The transformation of human technology from coarse stone tools in the Palaeolithic to pottery and metal tools in the Neolithic and Metal Ages offers an outline of technical evolution (engineering artifacts). Literature shows the lack of integration of this element of technological evolution in the pre-university science curriculum, even though it is important to build motivation and understanding of human evolution as a phenomenon of science and engineering [6].

Some of the challenges of teaching human evolution are due to several factors. First, the lack of teacher competence. Many teachers feel that they are not prepared enough to teach human evolution because the content is considered controversial or has not yet become part of the main curriculum [5]. Second, the lack of quality teaching materials. Studies of textbooks and lesson plans show that human evolution material is often sidelined, or only presented descriptively, without strong scientific evidence [6, 69]. Third, the aspect of student learning motivation. The presentation of human evolution through the everyday context and traits of human behavior tends to increase the engagement and relevance of science learning [5].

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Gamification and interactive media, such as the educational game PraksaraVerse, allow students to experience the process of evolution in a visual, exploratory, and interactive way. This is in line with modern recommendations that the use of digital content that combines aspects of behaviorism (direct feedback) and constructivism will increase motivation and understanding of science concepts, such as AI, immersive games, and quizzes.

The results of the SLR show that human evolution is a crucial topic in science education, but is still not effectively managed in the secondary school curriculum. Many students and teachers face limitations in valid material resources and pedagogic competence. Themes such as the destruction of the stone and metal age, the type of ancient humans, and the evolution of technology are still minimally explored in the context of scientific discussion, although the potential is very great for teaching science based on understanding the concepts and complexity of evolution.

Professional studies of teacher development show that learning approaches that involve direct interaction (e.g., 3D artifacts) and scientific discussion can increase self-efficacy in teaching human evolution. This provides a foothold that interactive applications such as PraksaraVerse can provide direct support to teachers and students (through adventure map features, prehistoric characters, adaptive quizzes, and technological mini-games) to build relevant, integrative, and evidence-based learning contexts.

Gamification and interactive media offer great opportunities in overcoming obstacles to student motivation and engagement due to their exploratory nature. By designing quizzes based on evolutionary science logic, interactive timelines, and mini games reconstructing ancient human tools, PraksaraVerse can serve as an *educational technology* that bridges the scientific, sociocultural, and engineering aspects of learning human evolution.

To provide a systematic overview of the focus of the literature review in this study, the author compiled a summary table of the *Systematic Literature Review* (SLR) that maps various main subchapters following the theme of developing the PraksaraVerse application as an interactive learning medium. This table contains key information regarding the scope of each subtheme, reference sources from reputable international journals indexed *by Scopus* (2023-2025), as well as key findings relevant to the development of content and features in digital learning applications. **Table 3** aims to (i) map the relationship between previous studies and theoretical frameworks and content design in PraksaraVerse, (ii) identify the latest research trends in the fields of interactive learning media, gamification, and human evolution, and 3) become the basis for the preparation of instructional design and content validation in the development of educational technology-based applications.

Table 3. Material content mapping.

Theme	Characteristic Findings	Recommendations for PraksaraVerse
Human evolution is often overlooked	There is a lack of curriculum and teaching materials	Provide comprehensive content from the Big Bang to modern humans
Timeline: the formation of the Earth, the Stone Age, and the metal age, as well as ancient humans and modern humans	Many textbooks present only one aspect	Digitize interactive timelines that support chronological sequences
Representation of ancient human types	Lack of genetic representation and environmental adaptation	Interactive visualization of Homo types with biological and sociocultural aspects

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Table 3 (Continue). Material content mapping.

Theme	Characteristic Findings	Recommendations for PraksaraVerse
Evolution of human technology	Rarely integrated into learning	Add mini games to build tools out of stone/metal
Teacher and pedagogical challenges	Not all teachers are ready to teach evolution	Include teacher modules: scientific and pedagogical references in the game
Gamification and interactive media	Effectively increase motivation & engagement	Use score indicators, adventure maps, and adaptive quizzes

3. METHODS

3.1. Research Design

This research uses a Research and Development (R&D) approach that refers to the Luther model [68]. This model was chosen because it has a systematic flow that is suitable for the development of technology-based digital media products, especially in the context of science and history learning. The Luther model consists of six main stages, namely concept, design, material collection, assembly, testing, and distribution. This research is focused on the development, testing, and evaluation of PraksaraVerse, which aims to improve the understanding of human evolution material. The process of research, development, and evaluation of PraksaraVerse is illustrated in **Figure 1**.

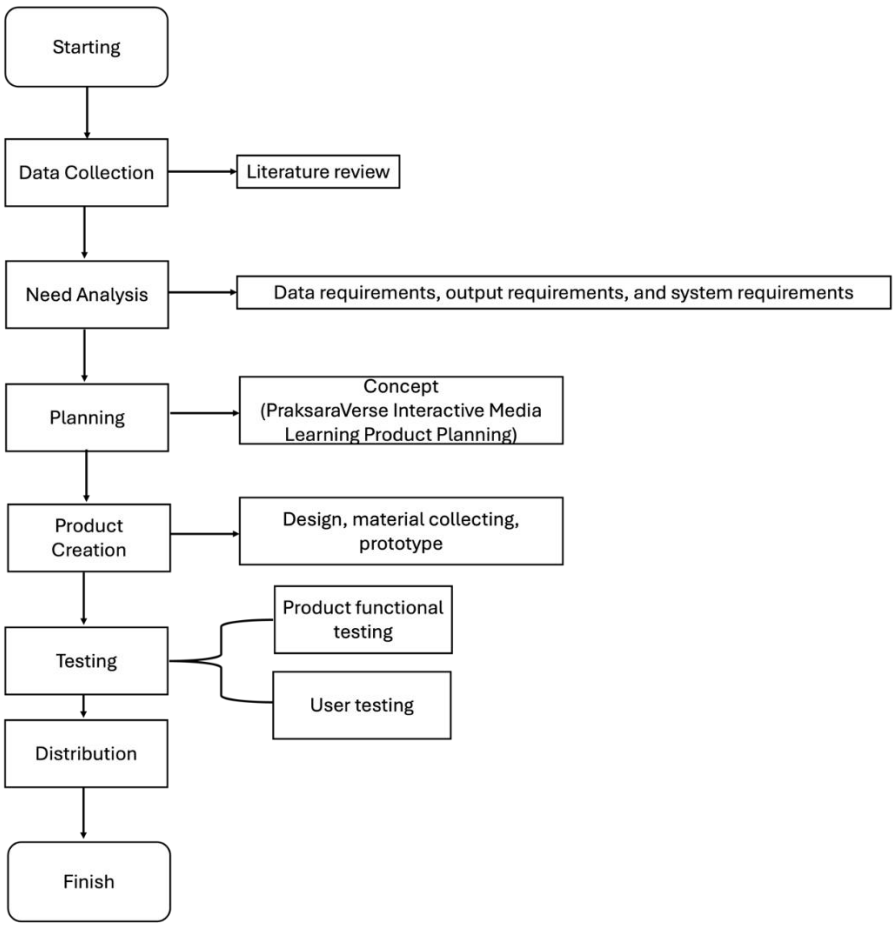

Figure 1. Research design.

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3.2. Population and Sample

The population in this study includes all high school students in the Special Region of Yogyakarta, especially those in three districts and cities, namely Yogyakarta City, Sleman Regency, and Bantul Regency. The selection of this region is based on the diversity of school characteristics, the readiness of digital infrastructure, and openness to technology-based learning innovations. The sample in this study was determined using purposive sampling techniques, focusing on grade 11 students who studied human evolution, prehistoric times, and early human cultural development. **Table 4** presents detailed information on the number of schools, the number of students, and the distribution of samples by location.

Table 4. Population and sample.

Location	School Name	Number of Classes	Number of Students	Classes Involved
Yogyakarta City	SMA Negeri 1 Yogyakarta	2	68	11 Grade Participative
Sleman Regency	SMA Negeri 2 Sleman	2	72	11 Grade Participative
Bantul Regency	SMA Negeri 1 Bantul	2	65	11 Grade Participative
Total	-	**6**	**205**	

3.3. Data Collection Instrument

The data collection instruments used in this study consist of two main types, namely perception questionnaires and concept comprehension tests. These two instruments are designed to provide a comprehensive overview of the effectiveness of using the PraksaraVerse application as an interactive learning medium in understanding human evolution and the context of prehistoric life. The student perception questionnaire was used to measure students' perception of the learning experience using PraksaraVerse, including aspects of interactivity, engagement, ease of use, visual appeal, and contribution to the understanding of the material. The questionnaire consisted of 20 statements, which were arranged on a five-point Likert scale, with the categories of strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1). Each item is designed to represent the quality dimensions of learning media, such as cognitive (ease of understanding of the material), affective (learning interest and motivation), technical (interface, navigation, and accessibility), and pedagogical (conformity to learning objectives). Before being used in the main data collection, the questionnaire was validated by three experts (two history education lecturers and one educational technologist), and tested on 30 students outside the main sample to ensure its validity and reliability. Cronbach's Alpha reliability value shows a value of 0.872, which is in the very high category, indicating that the questionnaire has excellent internal consistency.

In addition to perception questionnaires, concept comprehension tests are also used to support research needs. This test aims to measure the extent to which students' conceptual understanding of human evolutionary material and prehistoric life improves after using the PraksaraVerse app. The test is arranged in the form of a multiple-choice test, consisting of 30 questions that refer to learning outcomes. The questions in the comprehension test are designed to measure various cognitive levels according to the revised Bloom taxonomy, ranging from remembering (C1), comprehending (C2), to analyzing (C4). The questions are tested first to see the level of difficulty, differentiation, and validity of the question items. The

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results of the validity test showed that 26 out of 30 questions had a validity coefficient of >0.30 (moderate to high category), while the alpha reliability value of 0.803 indicated a good level of consistency.

3.4. Research Procedure

This research was carried out through a series of systematic stages designed to evaluate the effectiveness of the PraksaraVerse application as an interactive learning medium in improving students' understanding of the concept of human evolution and prehistoric life. The research procedure is divided into three main phases: application development, implementation in learning, and effectiveness evaluation.

At the application development stage, a needs analysis process was carried out based on the Indonesian history curriculum at the high school level, especially material on human life in prehistory and human biological evolution. Based on the results of the analysis, the initial design of the PraksaraVerse application was developed, which includes navigation structures, learning scenarios, interactive features (quizzes, animations, interactive maps), and science literacy-based materials. Material collection is carried out through literature studies and the selection of historical sources and relevant scientific articles, including from the fields of anthropology, archaeology, and evolutionary biology. After the material is collected, the process of assembling content into a digital platform is carried out using educational application development software. This process involves a team of educational technology developers, prehistoric material experts, and graphic designers. After the initial version of the application is completed, a limited trial (alpha testing) is carried out on a small group of students (n=10) who are not included in the main sample. The goal of this stage is to identify technical deficiencies (bugs, lag, UI/UX) and content (clarity of the material, difficulty level of the quiz, and visualization comprehension). Input from this trial is used to improve the application before it is widely deployed.

The implementation stage was carried out in the context of history learning in grade XI of high school using a quasi-experimental model of pretest-posttest design in one group. The sample consisted of students selected based on the purposive sampling technique, which is a class that has been scheduled to study prehistoric material. Students are given a pretest to find out their initial knowledge of the topic of human evolution. Furthermore, learning activities were carried out for two meetings using the PraksaraVerse application as the main media, replacing the conventional approach based on lectures and textbooks. During the learning process, students actively explore the in-app material, complete interactive quizzes, and conduct self-exploration on multimedia-based features such as 3D simulations of ancient humans and Stone Age cultural reconstructions. The teacher acts as a facilitator who guides the discussion and reflection process after students complete each session in the application. After the learning ends, a final comprehension test (posttest) is carried out, and a questionnaire is filled out for students' perception of the experience of using the application.

3.5. Methods for Analyzing Data

The data collected from the pretest and posttest were analyzed using descriptive and inferential statistical techniques (paired t-tests) to measure the improvement of student understanding. In addition, questionnaire data were analyzed to evaluate aspects of the app's quality from the user's point of view, including the dimensions of interactivity, visual appeal, learning motivation, and contribution to comprehension. The results of the quantitative analysis are then interpreted qualitatively by comparing the findings of previous research in

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the literature review. The triangulation process is carried out by matching test results, student perceptions, and observation of the learning process.

4. RESULTS AND DISCUSSION

4.1. Conceptualization

The development of *the PraksaraVerse application* begins with the conceptualization stage, which is the basis of the entire process of designing and implementing the application as an interactive learning medium based on history and science. The app is specifically designed to support the learning of human evolution and prehistoric life for high school students by bringing together historical and scientific approaches through Android-based digital technology. *PraksaraVerse* offers unlimited access to rich and interactive multimedia content. The material in this application is developed based on the curriculum structure and students' cognitive needs in understanding complex concepts such as the formation of the Earth, human evolution, and the development of ancient technology. The content is presented in a variety of formats, including high-quality images, three-dimensional animations, educational videos, and interactive illustrations.

The main features of this app include five aspects (**Table 5**). First, there is interactive navigation in the form of intuitive navigation buttons that allow transitions between subtopics to run smoothly and support free exploration by users.

Table 5. Features of praksaraVerse.

App Features	Description	Contribution to Learning
Interactive Navigation	Smooth transitions between chapters, digital concept maps, and important material bookmarking features	Improve learning independence and material navigation efficiency
Augmented Reality (AR)	Display ancient humans, stone tools, and Stone Age environments in virtual 3D	Improve students' spatial imagination and visual perception
Educational Videos & Films	Visualization material on the history of human evolution and prehistory with scientific narrative	Strengthening students' narrative understanding and memory of historical chronology
Quizzes and Self-Evaluation	Practice questions based on Bloom's Taxonomy from the knowledge level to evaluation	Measure conceptual understanding and critical thinking skills
Polls and Reflections	Open-ended and multiple-choice questions about the perception of evolution, cultural change, and the context of the present	Develop historical awareness and connection with contemporary issues

Second, there is augmented reality that provides AR features to display 3D models of ancient humans, stone tools, and prehistoric environments. Thus, students can explore historical objects virtually. Third, Educational Films and Learning Videos, which are compiled based on the chronological order of the history of human life from the beginning of the formation of the Earth to the Neolithic era. Fourth, Polls and Self-Reflection encourage students' involvement in critical thinking on reflective questions around cultural, technological, and environmental change. And the fifth is equipped with multiple-choice and short-form quizzes to measure students' understanding and retention of the material that has been presented.The treatment in this station goes through several phases shown schematically **Figure 1**.

Based on this conceptualization, *PraksaraVerse* not only functions as a provider of historical information but also as a learning medium that is exploratory, multimodal, and participatory. The approach used in the development of this application refers to the

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principles of technology-based learning, constructivism, and active learning experiences. The app is expected to be a transformative tool in history and science learning, particularly in bridging the gap between the theory of human evolution and students' concrete understanding through visualization and interaction.

4.2. Design

The design stage is an important foundation in the development of *the PraksaraVerse* application as an interactive learning medium based on history and science.

This stage is divided into two main parts, namely application design and *storyboard* design. The two complement each other to ensure that the flow of system logic and user experience runs in harmony with pedagogical goals. Application design begins with mapping the system flow through flowcharts.

This diagram illustrates the navigation structure and user interaction with the main features of the application. **Figure 2** shows a flowchart of *the PraksaraVerse* app system, which depicts the user's flow from the main page to various features such as learning materials, AR, videos, quizzes, and reflections.

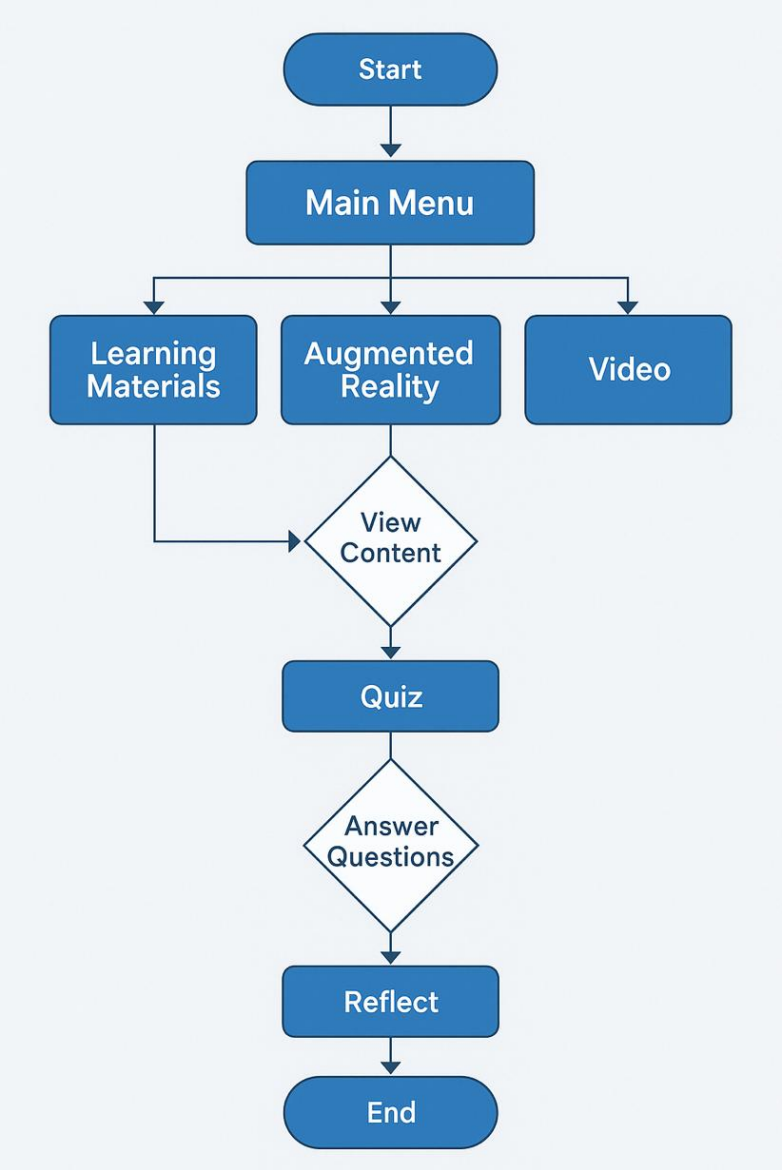

Figure 2. PraksaraVerse conceptual design.

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This diagram shows how users can select a subtheme from the main menu, then be directed to the material page, and then given the option to access additional content such as 3D visualizations, watch short documentary videos, or answer quizzes.

Each flow path is designed to return to the main navigation, so the learning experience is flexible and non-linear.

Storyboards are developed to describe each interface and interactive scenario visually and narratively in an application. Each scene on the storyboard describes the content, button functions, animations that appear, and the learning objectives you want to achieve.

This storyboard also presents a visual simulation of the user experience from the beginning of the application to the end of the learning session.

The storyboard coverage includes the Opening Page (PraksaraVerse logo animation, login button), Main Menu (Selection of topics such as Ancient Humans, Evolution of Stone Tools), Material Page (Illustration + narrative, with AR button and video options), AR Page (Ancient human 3D modeling with interactive gestures), Quiz Page (Multiple-choice questions, live feedback), and Reflection Page (Open-ended questions and opinion polls).

Each storyboard is annotated to explain the function of the buttons, transitions between screens, and the intended learning content. This aims to align graphic design with instructional goals and support the achievement of students' basic competencies.

4.3. Collecting Materials

The material collection stage in the development of *the PraksaraVerse application* is a fundamental part of the overall design and production process of this educational application. All materials are curated and developed in-house by the development team, which consists of history education lecturers, teachers, multimedia illustrators, and educational technology-based content developers.

The main objective of this process is to ensure that every element in the application, whether visual, text, sound, or animation, is in harmony with pedagogical goals, the national curriculum, and the scientific-historical approach related to human evolution and pre-literate life.

The collection of materials began with the mapping of high school curriculum-based content relevant to the topic of early humans and prehistoric periodization. The main materials focused on include the formation of the Earth, the characteristics of life during hunting and gathering, the period of cultivation, the period of retreat, and the development of stone and metal culture.

In addition, the content also includes an introduction to ancient human types in Indonesia and the world, such as *Homo erectus*, *Homo floresiensis*, and *Homo sapiens*, along with their biological and cultural evolutionary contexts.

All text content displayed in the app, such as narrative explanations, concept descriptions, dialogues in interactive features, and quizzes, is developed with a focus on language that is communicative, scientific, but still easy to understand for high school students.

The content writing team ensures that each narrative has a strong referential basis, draws on selected historical, archaeological, and anthropological literature, and is tailored to science-based learning principles.

From the visual side, the color scheme and typography are chosen with psychological and aesthetic considerations to create a fun and immersive learning atmosphere. The dominant color in the app is light blue (#6FC6E1), which is combined with the .gif and .png content backgrounds in pale blue (#C0E4FF), creating a fresh but less flashy visual atmosphere.

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The main title font uses the *soft green Cherry Bomb One* style (#E5FFE3), while the navigation buttons use the *dark blue Brosok* font (#134757), and general content, such as paragraphs and quizzes, use the neutral black *Tw Cen MT* font (#000000). This selection was made to distinguish the hierarchy of information in the application display and maintain visual comfort for users.

In the graphic and animation production process, the team used *Canva Pro* software to design backgrounds, icons, navigation buttons, and interactive page compositions. *Canva Pro* was chosen for its ability to produce high-quality, consistent visual displays across platforms.

For three-dimensional elements and interactive animations, developers use *the Assembler* site, which is a web-based platform that allows the creation of animated and simulated objects in the form of Augmented Reality (AR).

This feature is vital in *the PraksaraVerse* app, as it allows students to view 3D models of ancient humans directly in their surroundings through the device's camera, thus strengthening spatial and tactile understanding of matter.

In addition to text and illustrations, the app also presents educational videos that are independently produced by the team. This video includes a simulation of human evolution, a reconstruction of life in the pre-literate period, and a scientific explanation of the evolution of the times. For video creation, two main software programs are used, namely *Canva Pro* and *CapCut*.

Canva Pro is responsible for crafting storyboards, infographics, and graphic design elements, while *CapCut* is used for detailed audio-visual editing, including the insertion of narrative, background music, and transition effects.

The videos are then uploaded to the official PraksaraVerse YouTube channel, which also serves as an open repository for teachers and students to flexibly access materials outside of the app. The involvement of technology in the collection stage of this material is not only to improve the aesthetics of the application, but also to strengthen the pedagogical aspect.

For example, the *in-app polling* feature allows users to respond to hypothetical historical events, thus stimulating reflective thinking and context-based historical understanding.

Meanwhile, interactive quizzes and situational Judgment Tasks were developed as part of formative assessments, which can provide direct feedback to students regarding their understanding of the material learned.

As part of the validation of the material and interface, two stages of testing were carried out, namely alpha and beta testing. Alpha trials were conducted in a limited environment among developers and students to refine the technical and content aspects.

Furthermore, the beta trial was carried out involving 100 students from three high schools in Yogyakarta City, Sleman Regency, and Bantul Regency, to obtain quantitative and qualitative data related to the understanding, interest, and effectiveness of applications in science learning.

The results of this stage show a significant increase in the understanding of the concept of human evolution, as well as demonstrating the potential *of PraksaraVerse* as an adaptive learning medium based on cutting-edge technology.

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4.4. Assembly

An illustration of PraksaraVerse that has been developed using 2APK Builder is as follows.

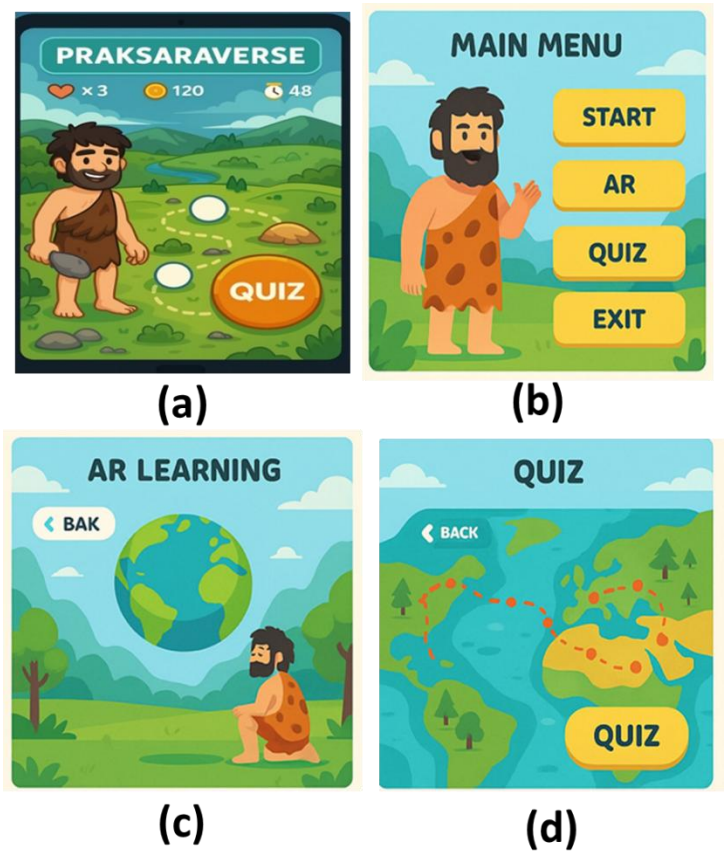

Figure 3. Assembly Processes and Visual Description: (a) Entry screen: The home screen displayed when you launch the application, (b) Main menu: The main navigation menu provides access to the core features of PraksaraVerse, (c) AR Learning: contains about Augmented Reality-based learning videos, and (d) Quiz: Contains questions to measure student understanding.

4.4. Testing

The trial of the *PraksaraVerse* educational application was carried out through a quasi-experimental approach involving two groups of students as participants, namely the Alpha group and the Beta group (**Table 6**). The main objective of this trial was to evaluate the effectiveness of *the PraksaraVerse* application in improving students' understanding of the topic of human evolution in the context of interactive digital-based history learning.

The research design used was *a non-equivalent control group design*, where the two groups received different treatments in the use of the application. The Alpha group was given the initial version of the product (version 1.0), while the Beta group used an improved version of the revised version of the Alpha test stage (version 2.0), which has been refined based on the findings and inputs in the initial test, both in terms of interface appearance, navigation flow, and depth of material.

Data was collected using a test instrument to pretest and posttest the use of the application. Descriptive statistics from the trial results showed an increase in average scores in both groups, but the Beta group showed a more significant improvement.

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Table 6. Trial score acquisition.

Group	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Average Difference
Alpha	64.15	8.21	72.40	7.95	8.25
Beta	63.90	8.09	78.25	6.78	14.35

The Alpha group experienced an average score increase of 8.25 points, while the Beta group experienced a higher increase of 14.35 points. This shows a marked difference in understanding between the two groups after using different versions of the application. To test the significance of the difference in improvement between the two groups, a difference test was carried out using *an independent sample t-test* on the gain score (difference between pretest and posttest).

The results of the differential test showed a t-value of 3.812 with a significance value *of p* = 0.000 ($p < 0.05$). This indicates that there is a statistically significant difference between the Alpha and Beta groups in terms of improved understanding of human evolutionary matters.

With a p-value well below the significance threshold of 0.05, the improved version of the PraksaraVerse application (Beta version) is significantly more effective in improving students' understanding of human evolutionary material than the Awa version.

This study aims to test the effectiveness of *PraksaraVerse* as an augmented reality (AR)-based interactive learning media in improving students' understanding of human evolution material. Based on the results of quasi-experiments with two different groups, namely the alpha group and the beta group, data showed that there was a significant difference in understanding between the two groups, where the beta group showed a higher improvement. This can be seen from the results of descriptive and inferential statistics conducted on the pretest and posttest scores of students in both groups.

Descriptively, the mean score of the posttest in the beta group was 87.23 with a standard deviation (SD) of 5.42, while the alpha group obtained an average score of 81.75 with an SD of 6.17. The analysis of the test was different from the *independent sample t-test technique* showed the values $t(104) = 3.812$ and $p = 0.000$ ($p < 0.05$), which indicated a statistically significant difference between the two groups in terms of improved understanding of the material.

These results support the hypothesis that the use of technology-based media such as *PraksaraVerse* can make a significant contribution to improving student understanding, especially when supported by interactive features and in-depth visual representations, as found in beta groups that get a complete and more dynamic version of the app. The beta group, in this trial, gained full access to all the app's features, including interactive 3D simulations, short documentaries on human evolution, reflective quizzes, and interactive maps of early human deployments. While the alpha group uses a limited version that does not include these features in full.

These findings are consistent with the results of previous research. Previous study [72] shows that the integration of AR in biology learning can significantly improve students' conceptual understanding of evolutionary processes because complex and interactive visualizations allow students to build better mental representations. AR allows students to not only read or hear concepts, but also to visually experience and explore how evolution unfolds in stages and stages.

In addition, previous research [69] found that AR-based learning can increase engagement and information retention because it facilitates an active, exploratory, and multimodal learning process. This is also the case with the use of *PraksaraVerse*, where students not only become passive recipients of information but also become active participants in exploring the

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process of human evolution, for example, by looking at 3D models of Homo erectus, Homo habilis, and Homo sapiens from different angles and comparing their morphological features through hands-on simulations.

From the perspective of learning theory, this finding can also be explained by the *cognitive theory of the multimedia learning approach,* the combination of words and images (dual coding) will be more effective in helping learners build mental models than just text or verbal. The features that PraksaraVerse possesses, such as evolutionary animation, interactive narratives, and adaptive quizzes, are in line with these principles as they facilitate the process of elaboration, association, and long-term memory retention.

Furthermore, the higher increase in the beta group also demonstrates the importance of the role of immersive learning experiences in enabling deep *learning*. Previous studies [70] stated that immersiveness in a virtual learning environment has a positive effect on motivation, engagement, and conceptual understanding. In this study, students in the beta group reported a more enjoyable learning experience and felt as if they were "directly involved" in the journey of ancient humans, which created an effect of presence and emotional involvement in the learning process.

Another important aspect that supports this result is the pedagogical adjustment in *the design of the PraksaraVerse*. The app integrates formative quizzes, polls, and self-reflection that all serve as scaffolding or learning buffers. This is in line with the principles of *formative assessment for learning,* which according to the literature [71, 72] is one of the strongest factors in improving learning achievement. With the instant feedback provided by the app after students complete the quiz, students can improve their understanding independently before moving on to the next material.

Although the results of the study show a positive impact of the use of *PraksaraVerse*, some limitations also need to be observed. First, although statistical tests showed significant results, the quasi-experimental design used did not allow for full control over external variables such as students' initial interest in history material or their level of digital literacy.

Second, the duration of the intervention is limited. Thus, it is not possible to measure the long-term effects of the use of the application on the retention of concepts or students' critical thinking skills.

Nevertheless, overall, these findings reinforce the argument that technology-based learning media such as *PraksaraVerse* can play a strategic role in improving the quality of science history learning, especially in complex and abstract topics such as human evolution. The app not only answers students' cognitive challenges in understanding the chronology and mechanisms of evolution, but also opens space for fun, interactive, and context-based learning experiences.

5. CONCLUSION

This research makes a significant contribution to expanding the use of interactive digital-based educational technology in learning about human evolution and preliteracy life. The *PraksaraVerse* application, designed with visual, narrative, and interactive quizzes approaches, shows great potential as a learning medium that is able to bridge the disconnect between abstract human evolutionary content and the way of thinking of today's digital generation.

The implications of this study lead to the need to integrate visual and contextual learning technologies into the curriculum in secondary schools. Learning is no longer enough to be delivered through lectures, text readings, or linear notes, but must reach a more

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participatory, exploratory, and multimodal way of learning, as demonstrated by the experience of using *PraksaraVerse*.

For educators, these findings emphasize the importance of openness to learning innovations as well as readiness to facilitate digital learning experiences that are integrated with science, culture, and historical contexts. Teachers are expected not only to be conveyors of past narratives, but also facilitators of technology-based learning that are able to build meaningful experiences for students. Meanwhile, for educational app developers, *PraksaraVerse* shows that collaboration between historical content, scientific approaches (such as human evolution), as well as visual and interactive design, is an effective strategy for creating relevant and impactful educational products.

This research also provides suggestions for education policymakers to start providing greater space in the education ecosystem for the development and use of research-based digital learning media. Integrating this kind of application in the curriculum can be a strategic step in presenting learning that is adaptive to the challenges of the digital era, without leaving behind a deep scientific substance.

In closing, *the PraksaraVerse* application is not just a teaching aid, but part of a pedagogical transformation towards more contextual, science-centric, and digital experience-based learning. Continued support for research and development of similar learning applications will strengthen the quality of Indonesian education in the future.

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7. AUTHORS' NOTE

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8. REFERENCES

[1] Mirzabek, R. (2023). The education and history of Timur Lenk from Uzbekistan. *Indonesian Journal of Educational Research and Technology*, 3(2), 105-110

[2] Harutyunyan, M. (2023). Exploring the rich tapestry of gardens and parks: A journey through history, education, and artistic expressions. *Indonesian Journal of Multidiciplinary Research*, *3*(2), 403-416.

[3] Mirzabek, R. (2023). The science education and history of Ulugh Beg: Astronomer and mathematician from Samarkand, Uzbekistan. *ASEAN Journal of Science and Engineering Education*, 3(1), 59-64.

[4] Hanisch, S., and Eirdosh, D. (2020). Educational potential of teaching evolution as an interdisciplinary science. *Evolution: Education and Outreach*, *13*(1), 25-51.

[5] Selba, M. C., Ziegler, M. J., Townley, A. L., and Antonenko, P. D. (2024). Exploring teacher self-efficacy in human evolution instruction following a dynamic hands-on professional development workshop. *Evolution: Education and Outreach*, *17*(1), 5-20.

[6] Hite, R. L. (2020). A content analysis of pre-college lesson plans on human evolution. *Disciplinary and Interdisciplinary Science Education Research*, *2*(1), 11-27.

[7] Bernacki, M. L., Greene, J. A., and Crompton, H. (2020). Mobile technology, learning, and achievement: Advances in understanding and measuring the role of mobile technology in education. *Contemporary Educational Psychology*, *60*, 101827.

[8] Ruiz-Bañuls, M., Gómez-Trigueros, I. M., Rovira-Collado, J., and Rico-Gómez, M. L. (2021). Gamification and transmedia in interdisciplinary contexts: A didactic intervention for the primary school classroom. *Heliyon*, *7*(6), e07374.

[9] Xayrullayevna, X.I., Furkat, A.F., Norimon, S.N., and Dilshod, R.S. (2025). Impact of innovative pedagogical approaches on student engagement and performance: A comparative study of flipped classrooms, gamification, and technology-enhanced learning. *Indonesian Journal of Multidiciplinary Research*, *5*(2), 247-254.

[10] Adeoye, M.A. (2023). Influence of gamification elements on students' academic performance. *Indonesian Journal of Teaching in Science*, *3*(2), 105-112.

[11] Attah, J.O., Ogunlade, O.O., and Falade, A.A. (2024). Students' attitude towards gamification-based teaching in mathematics in basic schools. *Indonesian Journal of Teaching in Science*, *4*(2), 121-128.

[12] Ekunola, G.T., Babalola, E.O., Omolafe, E.V., and Ibrahim, A.T. (2022). Undergraduate students' awareness to adopt gamification for learning in University of Ilorin, Nigeria. *ASEAN Journal for Science Education*, *1*(1), 17-22.

[13] Ayustyaningtias, R., Alinurdin, E., and Wahyudin, A. (2025). Improving students' critical thinking through blended learning media learning game word wall. *ASEAN Journal of Educational Research and Technology*, *4*(1), 51-58.

[14] Cabrillos, L.E., Gapasin, J.D., Marfil, J.A., and Calixtro Jr.V.L. (2023). Examining the effects of online games on the academic performance of BPEd students of Sultan Kudarat State University, Philippines. *Indonesian Journal of Educational Research and Technology*, *3*(1), 13-18.

[15] Marxabayevna, S.A. (2025). Game technologies and their impact on the personal development of children. *Indonesian Journal of Educational Research and Technology*, *5*(2), 107-112.

[16] Chakravarthi, S. S., Kannan, R. J., Natarajan, V. A., and Gao, X.-Z. (2022). Deep learning-based intrusion detection in cloud services for resilience management. *Computers, Materials and Continua*, *71*(3), 5117–5133.

[17] Sharma, R., Tan, C., Gomez, D., Xu, C., and Dubé, A. K. (2025). Guiding teachers' game-based learning: How user experience of a digital curriculum guide impacts teachers' self-efficacy and acceptance of educational games. *Teaching and Teacher Education*, *155*, 104915.

[18] Zhu, N., Zhao, F., Wang, L., and Dong, C. (2024). An enhanced Kalman filtering and historical learning mechanism driven estimation of distribution algorithm. *Swarm and Evolutionary Computation*, *86*, 101502.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2775-6793 e- ISSN 2775-6815

[19] Zukmadini, A.Y., Rohman, F., Dharmawan, A., Sari, M.S., Rochman, S., and Razak, S.A. (2024). Potential biodiversity from ethnozoology of Enggano Island: Utilization, a quantitative analysis, list of animals conserved by local people, and application of research findings empowering species literacy in biology student teachers. *Indonesian Journal of Science and Technology*, *9*(2), 463-496.

[20] Suprapto, P.K., Ardiansyah, R., Diella, D., Chaidir, D.M., Diana, S.W., Hendrawan, A.M., and Amarulloh, A. (2024). Plant anatomy: Definition, classification of plant organs and tissue, and design of a visuospatial transformation learning model for teaching biology. *Indonesian Journal of Science and Technology*, *9*(2), 557-584.

[21] Olumorin, C.O., Babalola, E.O., Aladesusi, G.A., Issa, A.I., and Omolafe, E.V. (2021). Experts' validation of the developed 3-dimensional automated model of the human heart to teach a biology concept in Ilorin, Nigeria. *Indonesian Journal of Multidiciplinary Research*, *1*(2), 299-308.

[22] Babalola, E.O. (2022). Design and development of 3-dimensional model of human circulatory system to teach a concept of biology in senior secondary schools. *Indonesian Journal of Teaching in Science, 2*(1), 17-28.

[23] Hofifah, S.N., and Sumiati, S. (2023). The effectiveness of the practicum video guide on distance learning in improving biology learning outcomes in enzyme content. *Indonesian Journal of Teaching in Science*, *3*(2), 201-212.

[24] Rizaldi, D. R., Nurhayati, E., and Fatimah, Z. (2020). The correlation of digital literation and stem integration to improve Indonesian students' skills in 21st century. *International Journal of Asian Education*, *1*(2), 73-80.

[25] Safitri, R. R., Rahmania, U. G., Putri, A. F., and Jumadi, J. (2025). The impact of game-based learning on student competencies in science: A systematic review. *Jurnal Pendidikan Dan Kebudayaan*, *10*(1), 116–136.

[26] Gui, Y., Cai, Z., Yang, Y., Kong, L., Fan, X., and Tai, R. H. (2023). Effectiveness of digital educational game and game design in STEM learning: A meta-analytic review. *International Journal of STEM Education*, *10*(1), 36-61.

[27] Oktadio, A. A., and Pardede, A. N. (2024). Development of interactive multimedia learning based on educational games in basic chemistry learning media. *Journal of Multimedia Trend and Technology*, *3*(1), 24–32.

[28] Ishak, S. A., Hasran, U. A., and Din, R. (2023). Media education through digital games: A review on design and factors influencing learning performance. *Education Sciences*, *13*(2), 102-122.

[29] Abidin, Z., Herman, T., Wahyudin, W., and Farokhah, L. (2025). Bibliometric analysis using vosviewer with Publish or Perish of computational thinking and mathematical thinking in elementary school. *ASEAN Journal for Science Education*, *4*(1), 7-16.

[30] Adebakin, A.B., Ajadi, O.T., and Akinniranye, O.I. (2025). Students' virtual classroom experiences in the post-COVID-19 era. *Indonesian Journal of Teaching in Science*, *5*(1), 61-72.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2776-6098 e- ISSN 2776-5938

[31] Adewumi, G.S., Akanbi, A.A., and Muraina, K.O. (2025). Effect of two instructional strategies on students' achievement in selected abstract concepts in biology. *Indonesian Journal of Teaching in Science*, *5*(1), 31-40.

[32] Ahillon Jr, R.C., Cadiong, S.R.C., Tomeldan, A.B., Belgira, A.C.B., Ayaya, A.R.A., Paredes, A.D.M., Balajadia, D.J.G., Sumandal, R.G.F., Basilio, L.D., and Quindra, K.C. (2025). Evaluation of robotics class in a private school in the Philippines. *ASEAN Journal of Educational Research and Technology*, *4*(1), 23-32.

[33] Arifiani, I., Nurul. H, L., and Rahmawan, S. (2025). Problem based learning (PBL) learning model for increasing learning motivation in chemistry subject: Literature review with bibliometric analysis. *ASEAN Journal for Science Education*, *4*(1), 17-30.

[34] Astaño, J.L. (2025). Development, validity, and acceptability of Android-based applications in ecology: A technology acceptance model (TAM) approach. *ASEAN Journal of Educational Research and Technology*, *4*(1), 91-106.

[35] Ayustyaningtias, R., Alinurdin, E., and Wahyudin, A. (2025). Improving students' critical thinking through blended learning media learning game word wall. *ASEAN Journal of Educational Research and Technology*, *4*(1), 51-58.

[36] Balasubramanian, K. (2025). The future of teaching: Artificial intelligence (AI) and artificial general intelligence (AGI) for smarter, adaptive, and data-driven educator training. *Indonesian Journal of Teaching in Science*, *5*(1), 49-54.

[37] Herath, H.M.M.N. (2025). Evolution and advancements from neural network to deep learning. *ASEAN Journal of Educational Research and Technology*, *4*(1), 59-80.

[38] Hidayat, A.N., Winarno, N., Afifah, R.M.A., and Ahmad, N.J. (2025). Analyzing junior high school students' cognitive load in a science subject: A case study. *Indonesian Journal of Teaching in Science*, *5*(1), 1-10.

[39] Kamraju, M. (2025). The ethical and educational implications of greenwashing in corporate sustainability practices. *ASEAN Journal for Science Education*, *4*(1), 45-52.

[40] Kazeem, S., Alhassan, N., and Falalu, M.K. (2025). Cultivating the pedagogical competence of pre-service science teachers through microteaching. *Indonesian Journal of Teaching in Science*, *5*(1), 21-30.

[41] Nadtayay, N., and Wongsaphan, M. (2025). Bibliometric analysis using VOSviewer with Publish or Perish of CEFR-based comparison of English language teaching models for communication. *ASEAN Journal of Educational Research and Technology*, *4*(1), 1-10.

[42] Ogundele, A.G., Umar, I.Y., and Idris, A.M. (2025). The emergence of new technologies in metalwork/automobile industries: Issues, challenges and opportunities in emanating from for delivery of technical education on a pandemic era. *ASEAN Journal for Science Education*, *4*(1), 1-6.

[43] Pecson, R.R., and Sarmiento, J.R. (2025). Student teaching and instructional materials in the 21st-century classroom: A literature review. *Indonesian Journal of Teaching in Science*, *5*(1), 55-60.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2775-6793 e- ISSN 2775-6815

[44] Pratiwi, D.T., Zahratunnisa, F., and Rahmawan, S. (2025). The impact of project-based learning (PjBL) on students' motivation and learning outcomes: A literature review. *ASEAN Journal for Science Education*, *4*(1), 53-58.

[45] Ragadhita, R., Sriyati, S., Nahadi, N., Rustaman, N., and Kaniawati, I. (2025). Context evaluation in nanotechnology courses: A context, input, process, and product (CIPP) model perspective. *Indonesian Journal of Teaching in Science*, *5*(1), 73-92.

[46] Liu, Y., Lin, Y., Shi, R., Luo, Y., & Liang, H. N. (2021). RelicVR: A virtual reality game for active exploration of archaeological relics. *CHI PLAY 2021 - Extended Abstracts of the 2021 Annual Symposium on Computer-Human Interaction in Play*. https://doi.org/10.1145/3450337.3483507

[47] Sackdanouvong, K. (2025). An investigation of factors that motivate academics to conduct research and research productivity in Lao Public Universities. *ASEAN Journal of Educational Research and Technology*, *4*(1), 39-50.

[48] Saidirasilovna, U.N. (2025). Preparing future geography teachers through problem-based learning technology: A short review. *ASEAN Journal for Science Education*, *4*(1), 39-44.

[49] Salman, A.A., and Yahaya, O. (2025). Perception of early childhood education lecturers on the use of virtual learning. *ASEAN Journal for Science Education*, *4*(1), 31-38.

[50] Salomova, R.V. (2025). The effectiveness of blended education in educational institutions. *ASEAN Journal of Educational Research and Technology*, *4*(1), 33-38.

[51] Sirodjovna, I.O., and Abduraxmon, K.N. (2025). The impact of phonetic rhythmicity on speech and communication skills of elementary students with special needs. *Indonesian Journal of Teaching in Science*, *5*(1), 41-48.

[52] Sonjaya, R.P., and Munir, M. (2025). Examining the impact of block-based visual programming in programming education: A systematic review. *Indonesian Journal of Teaching in Science*, *5*(1), 11-20.

[53] Sulyman, H.T., Jimoh, F.A., and Giwa, A.B. (2025). Effect of cross-over learning on pupils' academic performance in civic education. *ASEAN Journal of Educational Research and Technology*, *4*(1), 81-90.

[54] Tarraya, H.O., Camposano, C.E., Rojo, S.G., Dolorica, M.C.C., Polon, J.H., and Digo, G.S (2025). Emerging technologies for sustainable universities and colleges: A meta-synthesis. *ASEAN Journal of Educational Research and Technology*, *4*(1), 11-22.

[55] Umeohana, T.E. (2025). Assessment of instructional material relevance and availability for biology education. *Indonesian Journal of Teaching in Science*, *5*(1), 93-100.

[56] Khairunnisya, M., Herlina, S., Angraini, L. M., Suripah, and Suripah. (2021). Development of Educational Game-Basedlearning Media Byconstruct2. *Mathematics Research and Education Journal*, *5*(2), 11–19.

[57] Akhmetova, A. I., Seitenova, S. S., Khodjaev, B. K., Jamoldinova, O. R., Yerkebaeva, S. Z., and Kazybayeva, K. U. (2025). Evolution of game-based learning research: A cross-database bibliometric analysis and visualization study (2015-2024). *Contemporary Educational Technology*, *17*(3), ep585.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2776-6098 e- ISSN 2776-5938

[58] Behnamnia, N., Kamsin, A., and Hayati, S. (2024). Impact of Digital Game-Based Learning on STEM education in primary schools: A meta-analysis of learning approaches. *Innoeduca. International Journal of Technology and Educational Innovation*, *10*(2), 113–140.

[59] Nelson, C. R., and Gabbard, J. L. (2023). Pedagogical design considerations for mobile augmented reality serious games (MARSGs): A literature review. *Electronics*, *12*(21), 4524.

[60] Luo, Z. (2023). The Effectiveness of Gamified Tools for Foreign Language Learning (FLL): A Systematic Review. *Behavioral Sciences*, *13*(4), 331.

[61] Jaramillo-Mediavilla, L., Basantes-Andrade, A., Cabezas-González, M., and Casillas-Martín, S. (2024). Impact of gamification on motivation and academic performance: A Systematic review. *Education Sciences*, *14*(6), 639.

[62] Zeng, J., Sun, D., Looi, C., and Fan, A. C. W. (2024). Exploring the impact of gamification on students' academic performance: A comprehensive meta-analysis of studies from the year 2008 to 2023. *British Journal of Educational Technology*, *55*(6), 2478–2502.

[63] Ruiz, J. J. R., Sanchez, A. D. V., and Figueredo, O. R. B. (2024). Impact of gamification on school engagement: a systematic review. *Frontiers in Education*, *9*, 1-10.

[64] Nurfadilah, N., Bancong, H., Saad, R., and Fiskawarni, T. H. (2025). Direction of Gamification in Science Education: Literature Review and Indexed Bibliography. *International Journal of Learning, Teaching and Educational Research*, *24*(4), 568–591.

[65] Almeida, C., Kalinowski, M., Uchôa, A., and Feijó, B. (2023). Negative effects of gamification in education software: Systematic mapping and practitioner perceptions. *Information and Software Technology*, *156*, 107142.

[66] Hanisch, S., and Eirdosh, D. (2023). Developing teacher competencies for teaching evolution across the primary school curriculum: A design study of a pre-service teacher education module. *Education Sciences*, *13*(8), 797-827.

[67] Panayides, A., Sá-Pinto, X., Mavrikaki, E., Aanen, D. K., Aboim, S., Cavadas, B., Dvorakova, R. M., Eens, M., Filova, E., Gregorčič, T., Kapsala, N., Nieuwenhuis, M., Ometto, L., Papadopoulou, P., Pinxten, R., Realdon, G., Ribeiro, N., Coelho da Silva, J. L., Sousa, B., and Korfiatis, K. (2024). Evolution content in school textbooks: Data from eight European countries. *Evolution: Education and Outreach*, *17*(1), 11-27.

[68] Sodikin, S., Efendi, Y., and Yatimollah, Y. (2023). Implementation of the multimedia development life cycle in making educational games about Indonesia. *Journal of Computer Engineering, System and Science*, *8*(2), 595-606.

[69] Xu, C., Xu, L., Zhao, S., Yu, L., and Zhang, C. (2024). Complementary knowledge augmented multimodal learning method for yarn quality soft sensing. *Engineering Applications of Artificial Intelligence*, *133*, 108057.

[70] Fendi, R. D., Suyatna, A., and Abdurrahman, A. (2021). Augmented reality-based student worksheet to stimulate students' critical thinking skills. *Indonesian Journal of Science and Mathematics Education*, *4*(2), 118–133.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2775-6793 e- ISSN 2775-6815

[71] Mulders, M., Buchner, J., and Kerres, M. (2020). A Framework for the use of immersive virtual reality in learning environments. *International Journal of Emerging Technologies in Learning*, *15*(24), 208-224.

[72] Leenknecht, M., Wijnia, L., Köhlen, M., Fryer, L., Rikers, R., and Loyens, S. (2021). Formative assessment as practice: The role of students' motivation. *Assessment & Evaluation in Higher Education*, *46*(2), 236-255.

DOI: https://doi.org/10.17509/ajse.v5i3.89109
p- ISSN 2776-6098 e- ISSN 2776-5938