Developing an android-based interactive multimedia application for integrated science instruction at the junior high school level

Deitrisye Darumba[1*], Anatje Lihiang[2], Meike Paat[2], Aswin Mandolang[2], Emma Moko[2] and Jovialine Albertine Rungkat[2]

[1] Master's Program in Science Education, Postgraduate Program, Manado State University, Indonesia

[2] Science Education Study Program, Postgraduate Program, Manado State University, Indonesia

Correspondence Author: Deitrisye Darumba

Received 3 March 2025; Accepted 2 Apr 2025; Published 24 Apr 2025

Abstract

This study aimed to develop and evaluate an Android-based interactive multimedia for integrated science learning (IPA Terpadu) at a junior high school. Using a Research and Development (R&D) design guided by the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), the product was created with content on the human circulatory system and packaged into an APK via iSpring Suite and Website 2 APK Builder Pro. Expert validation occurred in two rounds: material experts initially scored 69% (needing revision) and, after revision, 87% (highly valid), while media experts improved from 58.2% to 87% (highly valid) upon revalidation. Practicality trials with teachers and students indicated that the application was "practical" for classroom use. Effectiveness was measured by pre- and post-test embedded within the app; nine students achieved a total score of 766 (mean = 85), classifying the product as "effective" according to school criteria. The findings demonstrate that the developed multimedia is valid, practical, and effective, offering a self-paced, accessible solution for teaching abstract science concepts, especially in contexts with limited internet access.

Keywords: Android-based interactive multimedia, Integrated science learning, ADDIE model, Research and development

1. Introduction

Education constitutes the bedrock of a nation's advancement. In the contemporary era, the educational sector faces intricate and evolving challenges. Technological innovations, social transformations, and heightened quality expectations are among the principal factors shaping current educational trajectories. Addressing these challenges necessitates continual innovation and quality enhancement to ensure that education remains effective and pertinent in the modern context. In Indonesia, education has transitioned into a new phase marked by curriculum reform. The shift from the 2013 Curriculum (K-13) to the Merdeka Curriculum did not occur arbitrarily; rather, it reflects evolving societal demands and needs (Putri, 2019) [34]. This reform underscores the increasing emphasis on critical thinking, creativity, and problem-solving skills within the learning process.

Learning is an interactive activity involving both students and teachers, drawing upon diverse instructional resources to achieve desired educational outcomes. The success of this process depends on the degree to which each component (e.g., instructional materials, teacher facilitation, and learner engagement) interacts effectively. Beyond traditional printed textbooks and modules, technological tools have emerged as vital learning resources (Dimyati & Mudjono, 2009; Mokalu, et al., 2023; Kahar, et al., 2020; Kawuwung, et al., 2018) [10, 17, 12, 13]. Advances in educational technology have enabled educators to better harness students' potential (Munir, 2010) [21]. As science and technology evolve, new technological solutions emerge to address instructional challenges (Arsyad, 2011) [4]. Integrating technology into teaching can transform the classroom dynamic, which often remains teacher-centered, where students passively listen, observe, and imitate. In contrast, interactive media allow students to access information from diverse sources, fostering greater autonomy in learning (Siregar, et al., 2019; Paat & Mokalu, 2023) [42, 25].

An observation at SMP Negeri 5 Satap Kombi—located in the remote Kinaleosan village, Kombi subdistrict, Minahasa regency—revealed limited internet connectivity, although the school possesses Chromebooks, computers, and LCD projectors, and students own smartphones with constrained internet access. Moreover, the school implements both the 2013 Curriculum and the Merdeka Curriculum: the former aims to strengthen students' competencies across knowledge, skills, and attitudes, while the latter prioritizes student interests and talents. During an interview on Monday, February 10, 2025, with the vice-principal, Mr. Ofrie Tangkulung, S.Pd, it was noted that instructional media remain largely text-based and teacher-centered, underutilizing available technological facilities. Science teachers reported that their instruction relies heavily on textbook images; sourcing additional videos or graphics is challenging due to internet limitations. Specifically, the human circulatory system—the topic under study—remains abstract when taught textually, with learning materials limited to static diagrams of organs. Despite some variation in media use, current practices are suboptimal, leading to student disengagement. One teacher observed: "Most students struggle to distinguish arteries from veins and capillaries, and many cannot explain how blood is pumped from the heart to the body and back" (Interview, February 10, 2025). A student in Grade VIII, Kelina, confirmed this, stating, "I find learning about the circulatory system uninteresting because the material is too difficult to grasp."

Science, by its nature, encompasses extensive and complex content. Effective instruction therefore requires more than verbal explanations; it must integrate visual and auditory elements to convey concepts clearly (Widayat et al., 2014; Sanudin, et al., 2023) [55, 40]. Within the Grade VIII Indonesian middle school curriculum, the integrated science topic "Human Circulatory System" appears under "Structure and Function of Living Organisms." A prominent instructional issue is the lack of technologically enriched materials and media, resulting in a learning environment that is neither efficient nor engaging.

Interactive multimedia— defined as a combination of text, graphics, photographs, animations, video, and audio presented in an interactive format—can render abstract concepts more concrete, facilitating deeper student comprehension. Through active and enjoyable engagement, learning becomes more meaningful (Paat, Sutopo & Siregar, 2019; Lelamula, et al., 2022) [28, 16]. According to Aqib (2007) [2], humans acquire 75% of new knowledge through sight, 13% through hearing, and 12% through taste, touch, and smell. Furthermore, Dale's Cone of Experience suggests that multisensory engagement enhances retention (Arsyad, 2011) [4]. Consequently, interactive multimedia offers significant advantages for integrated science instruction: it stimulates students' attention, interest, cognition, and affect, while also providing opportunities to develop skills in problem identification, information organization, analysis, evaluation, and communication (Munir, 2010; Pertiwi, et al., 2023; Patibang, et al., 2025) [21, 31, 30].

Empirical studies corroborate the efficacy of multimedia in education. Firmansyah (2024) demonstrated that multimedia enhances student motivation and learning outcomes. Similarly, Muhammad Kifron (2024) found that interactive multimedia increased student engagement, and Andi Putra (2014) [33] reported that interactive multimedia substantially aided both teachers and learners in the instructional process. By enabling direct interaction between students and educational content, interactive multimedia supports students in keeping pace with technological advancements and accommodates individual learning abilities, pacing, and preferences. Given these benefits, interactive multimedia plays a critical role in learning, prompting the need to develop such media for instructional purposes.

2. Materials and methods

The term *media* originates from the Latin word *Medius*, signifying "middle," "intermediary," or "conduit." In Arabic, it similarly denotes an intermediary that conveys messages from sender to receiver. *Media* is the plural of *medium*, both connoting an agent that facilitates transmission. Meanwhile, the Indonesian term *pembelajaran*translates the English "instruction," defines as a dynamic, interactive process between teacher and learner. Further characterizes learning as a communicative endeavor in education, one guided by specific objectives. Instructional media encompasses any resource capable of transmitting content, messages, or lessons in ways that stimulate students' cognitive processes, emotions, attention, and overall learning ability, thereby promoting an effective teaching–learning environment. (Sanjaya, 2010; Munandi, 2008; Arsyad, 2011; Tampinongkol, et al., 2022) [39, 19, 6, 49].

Drawing upon these definitions, instructional media emerges as a vital tool for delivering intended content to learners in a structured fashion that aligns with pedagogical goals. In educational practice, student achievement often hinges on the instructional process—particularly the educator's capacity to convey knowledge effectively. Many students exhibit disengagement when teachers rely on monotonous delivery methods or lack the skills to package material engagingly. In today's globalized context, technological advancements have greatly expanded the range of available learning resources, shifting much of the information from traditional libraries to online platforms. Consequently, educators must emphasize strategies that capture students' interest spontaneously— for example, by incorporating varied media to enrich the learning experience. (Sondakh, et al., 2021; Paat, et al., 2024; Umar, et al., 2022; Onsu, et al., 2023) [43, 27, 23].

Aqib (2007) [2] demonstrates that new knowledge is acquired 75% through visual channels, 13% through auditory channels, and 12% through gustatory, olfactory, and tactile experiences. The integration of appropriate instructional media thus supports students' meaningful comprehension and experiential engagement. Yet, as Yudi (2008:185) observes, many educators limit their use of media to static images or rudimentary animations displayed via slide projectors, thereby underutilizing the potential of multimedia to enhance learning. Dale's theory posits that students' retention improves as more senses are engaged during learning activities (Arsyad, 2011) [6]. Interactive multimedia, in particular, offers substantial benefits for integrated science education. Integrated science instruction merges disciplines such as physics, chemistry, and biology into a cohesive whole, thereby enabling learners to construct their own understanding and to recognize the interconnections among different scientific concepts. This approach fosters meaningful learning and aligns with the Indonesian Ministry of Education and Culture's Regulation No. 22 of 2006, which mandates that junior high school science curricula adopt an integrated framework (BSNP, 2006) [8]. The 2013 Curriculum further reinforces this by emphasizing the holistic development of students' knowledge, skills, and attitudes.

Science education aims to cultivate students' understanding of both themselves and the natural world, grounded in principles that explain universal phenomena. However, many science topics are inherently abstract and not directly observable, which can leave students with vague or incomplete mental models. Effective science instruction thus requires that students not only think critically but also actively engage—solving problems, exploring solutions, and employing all their senses.

Research by Jacob and Schade (as cited in Munir, 2010) [21] indicates that passive reading yields the lowest retention rates (approximately 1%), whereas adding audiovisual media, such as television, can raise retention to 25–30%. Furthermore, three-dimensional multimedia can boost retention up to 60%, as it efficiently and effectively presents 3D concepts within a systematically designed, communicative, and interactive curriculum. Consequently, incorporating multimedia into science instruction aligns well with students' creative and innovative capacities. By involving multiple sensory modalities—visual, auditory, and kinesthetic—interactive multimedia enhances engagement and makes learning experiences more compelling and memorable.

According to Munandi (2013) [20], instructional media can be characterized as follows:

a) Visual media

Visual media engage the learner's sense of sight and encompass two categories of messages: verbal (i.e., written language) and nonverbal–visual (i.e., symbols). Nonverbal–visual messages may take various forms:

- **Images:** These include sketches, paintings, and photographs. Sketches or line drawings are simplified drafts that depict the essential features of an object without intricate detail. Paintings represent a symbolic and artistic rendition of an object or situation, while photographs are captured images produced via a camera. Such imagery enables educators to animate learning environments and assist students in conceptualizing content more vividly.
- **Graphs:** A graph is a visual representation of quantitative data presented in a simplified, easily interpretable format. Transforming numerical information into graphical form helps clarify data relationships. Common graph types include:
  - **Line graphs**, which plot data points connected by lines on a Cartesian grid.
  - **Bar graphs**, which use rectangular bars (either two-dimensional or three-dimensional) to represent data values.
  - **Pie charts**, which depict data as sectors of a circle, indicating proportional relationships.
- **Diagrams:** Diagrams consist of schematic drawings—often resembling maps—used to illustrate spatial relationships or components within a system. For example, a classroom layout diagram shows the arrangement of walls, doors, windows, desks, chairs, and other furnishings.
- **Charts (Flowcharts and Organizational Charts):** A chart typically emphasizes progression, processes, or organizational structures.
  - An organizational chart illustrates the hierarchy and relationships within an institution or group.
  - A flowchart depicts sequential steps in a process, analogous to tributaries converging to form a river.
  - A tree diagram resembles a branching tree to demonstrate how one entity may give rise to multiple sub-entities.
  - A process chart delineates the stages involved in producing a certain outcome.
- **Maps:** Maps are pictorial representations of the Earth's surface (or a portion thereof) that convey geographic information.

Verbal–visual channels—media that combine verbal language with visual elements—include:

- Textbooks and learning modules
- Comics
- Magazines and academic journals
- Posters
- Visual display boards

b) Audio media

Audio media engage the auditory sense and involve a complex process comprising four stages: (1) hearing, (2) attending, (3) comprehension, and (4) retention. Learners must not only hear the material but also focus on it, understand its meaning, and finally commit it to memory. The advantages of audio media include:

- Overcoming spatial and temporal limitations, thereby reaching a broader audience.
- Stimulating listeners' imagination.
- Focusing learners' attention on the use of language, sounds, and their significance.
- Being ideally suited for teaching music and language.
- Influencing learners' moods and behaviors.

Common formats for audio media are:

- Vinyl records
- Open-reel tape recorders
- Audio cassette recorders
- Compact discs (CDs)
- Radio broadcasts
- Language laboratories

c) Audio–visual media

Audio–visual media are often regarded as the most complete form of instructional media because they simultaneously engage both sight and hearing. Two principal categories exist:

- **Pure audio–visual media,** such as television broadcasts, motion picture films, and videos, which integrate synchronized audio and visual content.
- **Hybrid audio–visual media,** such as slides and overhead projectors (OHP), which combine still images with audio commentary.

Development of interactive multimedia as an instructional medium

Etymologically, the term *multimedia* derives from the Latin *multi* ("many, several") and *medium* ("means of conveyance"). Haffost defines multimedia as a computer-based system—comprising hardware and software—that facilitates the integration of images, videos, photography, graphics, and animations with audio, text, and data under the control of computer programs (Munir, 2010) [21]. A simpler definition indicates that multimedia involves more than one medium concurrently, engaging multiple senses in the learning experience (Arsyad, 2011:170) [6]. The Indonesian dictionary (KBBI, 2017) [14] defines *interactive* as "mutually reactive" or "jointly active," aligning with Warsita's assertion that interactive multimedia is an instructional medium capable of synthesizing text, graphics, photographs, video, animation, music, narration, and interactive features based on pedagogical theory and principles (Warsita, 2008:36; Silangen, et al., 2024; Kindangen, et al., 2023) [52, 41, 15].

From these definitions, interactive multimedia can be conceptualized as a highly complex resource designed with creative and innovative programming to foster reciprocal interaction within the learning process. In accordance with Dale's Cone of Experience, multimedia provides a direct experiential learning opportunity by involving multiple senses; students can readily associate objects with concepts, colors with meanings, sounds with memories, and physical actions with specific information (Yudi, 2008:19). In a multimedia-based instructional setting, learners engage with interactive CD- or VCD-based content that often includes embedded quizzes to reinforce comprehension.

Asyard (2012) proposes five criteria for quality multimedia learning materials:

- **Visually appealing design:** The graphical layout and color combinations must be engaging and aesthetically coherent.
- **Clear and comprehensible narration:** Audio-narrated text should be articulate and easily understood by learners.
- **Interactive content delivery:** The material must provide feedback mechanisms so that learners can receive immediate responses.
- **Alignment with learner characteristics, content, and objectives:** The instructional design should reflect students' cognitive levels, the nature of the subject matter, and the targeted learning outcomes.
- **Feasibility of Implementation:** The necessary technical and logistical support (e.g., hardware, software, network infrastructure) must be available to ensure smooth operation.

Gagné (as cited in Munir, 2010) [21] notes that multimedia-based instruction can be implemented in both group and individual learning formats, depending on the instructional design and learner needs.

Categories of interactive multimedia

Suryanto distinguishes two principal forms of interactive multimedia:

- Online Interactive Multimedia, which is delivered via network connections (e.g., websites, messaging platforms like Yahoo Messenger). This category is considered *upper-tier media*, as it addresses a broad and diverse audience.
- Offline Interactive Multimedia, which operates without real-time network access (e.g., interactive CDs). Classified as *lower-tier media*, it targets more localized communities (Bernardo, 2011; Tangdilian, et al., 2023) [48].

Android

Android is a Linux-based operating system for mobile devices, encompassing the operating system itself, middleware, and applications. As Akhmad Dharma Kasman states, "Android is a touchscreen-oriented operating system for smartphones and tablets based on Linux." Over time, Android has rapidly evolved as a platform, largely driven by Google's acquisition and subsequent development efforts. The Android ecosystem consists of a Linux kernel-based operating system, a graphical user interface (GUI), a web browser, and end-user applications that are freely downloadable. Moreover, developers have considerable freedom to create and distribute applications compatible with diverse hardware platforms.

Advantages of android as an educational platform

Android offers several attributes that make it highly suitable for educational applications:

- **Wide accessibility:** As a ubiquitous platform, Android devices come in various configurations and price points, facilitating adoption in both developed and developing regions.
- **Flexibility and customization:** Educators and developers can tailor Android applications to align closely with specific curricula and instructional objectives.
- **Interactive and engaging experience:** Android supports multimedia integration—images, audio, video, and animations—enhancing learner engagement and interactivity.
- **Portability:** The mobile nature of Android devices enables learning to occur anywhere, provided there is internet connectivity or downloaded content.
- **Tracking and evaluation:** Many Android learning apps include built-in analytics that allow instructors to monitor student progress and identify areas requiring targeted support.
- **Ease of sharing and collaboration:** Android's connectivity features facilitate the distribution and collaborative use of learning materials, assignments, and resources.
- **Self-directed learning opportunities:** With access to educational apps, students can pursue individualized learning paths at their own pace, independent of time and location constraints.
- **Cost-effectiveness:** Numerous educational applications on the Android platform are available free of charge or at minimal cost, offering an affordable alternative to traditional learning resources.
- **Multilingual support:** Android's inherent support for multiple languages permits its deployment in diverse cultural and linguistic contexts.
- **Integration with emerging technologies:** Android can interface with device sensors, cameras, and emerging technologies such as virtual and augmented reality (VR/AR), enriching the pedagogical experience.

Despite these advantages, effective implementation of Android-based learning media necessitates careful instructional design, rigorous content development, and ongoing evaluation to ensure that pedagogical objectives are successfully met.

Development of interactive multimedia programs

The primary emphasis in designing and developing interactive multimedia programs is ease of use, alignment with knowledge-building objectives, enhancement of learners' skills and creativity, and incorporation of interactive elements and feedback mechanisms (Sadiman et al., 2009; Sondakh, et al., 2021) [38, 43]. Although there is no universally mandated protocol for multimedia design, developers must possess the expertise to tailor instructional content to learners' needs. Interactive multimedia affords learners far greater control than many other media types; students can determine the depth, scope, and selection of content while engaging directly with the program. According to Sugiyono (2015) [45], to develop (mengembangkan) means to deepen, expand, and refine existing knowledge, theories, and products so that they become more effective and efficient. Thus, the central goal of interactive multimedia development is to package learning materials in ways that are user-friendly and readily integrated into pedagogical activities.

The human circulatory system

The study of the human circulatory system exemplifies the integration of biology, physics, and chemistry. Within the "Structure and Function of Living Organisms" unit of the Grade VIII Merdeka Curriculum for Integrated Science—SMP/MTs—students explore the transportation systems of the human body. Blood consists of plasma and cellular components, functioning as a fluid that travels through blood vessels to facilitate transport, deliver oxygen (O_2) and carbon dioxide (CO_2), combat pathogens, and maintain thermal homeostasis. Two interrelated subsystems compose the circulatory system: the cardiovascular system—comprising the heart, blood vessels, and blood—and the lymphatic system, which includes lymphatic vessels and lymph fluid. By volume, blood is approximately 55% plasma and 45% formed elements (erythrocytes, leukocytes, and platelets). Monitoring blood pressure is a routine diagnostic procedure, commonly expressed numerically (e.g., 120/80 mmHg, where 120 indicates systolic pressure and 80 indicates diastolic pressure). Blood pressure values vary according to age, sex, and activity level. As a fluid, blood can travel to the brain and other organs because the heart continuously pumps it throughout the body.

Research methodology

This study employed a mixed-methods design, specifically a Research and Development (R&D) approach, to create a tangible educational product. The intended outcome is an Android-based interactive multimedia application designed to support integrated science instruction (IPA) at the junior high level. Development followed the ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) as outlined by Sugiono (2015). The procedural flow is described below:

Development procedure

The ADDIE model guided the creation of the instructional multimedia through five distinct phases: Analysis, Design, Development, Implementation, and Evaluation.

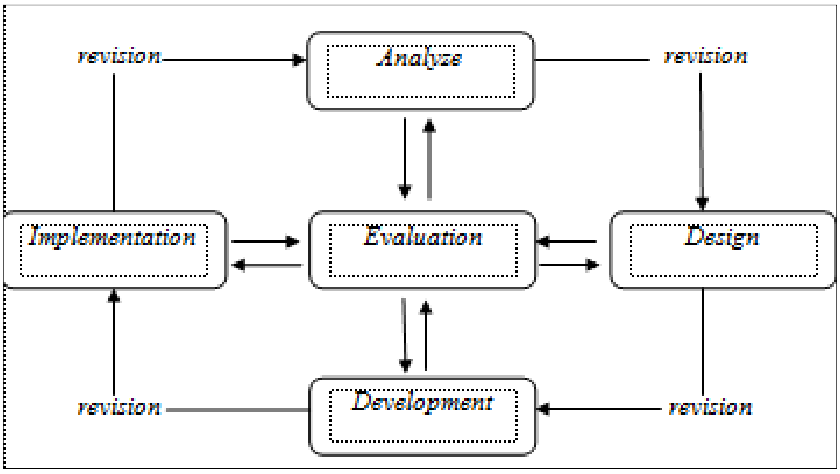

Fig 1: The Stages of the ADDIE Instructional Design Model

I. Analysis

The primary objective of the Analysis phase was to identify and justify the need for a new instructional medium. Following Pribadi (2009) [32], this phase encompassed four key analyses:

- **Curriculum analysis:** The research team first determined the relevant curricular frameworks at SMP Negeri 5 Satap Kombi. Through observations and interviews with the vice principal and science faculty, it was established that the school implements the Merdeka Curriculum for Grades 7 and 8, and the 2013 Curriculum (K-13) for Grade 9.
- **Needs analysis:** Observations at SMP Negeri 5 Satap Kombi revealed a strong demand for interactive multimedia. Historically, instruction had relied heavily on printed textbooks and teacher-centered methods, with minimal use of technology. Nevertheless, the school possesses essential hardware—including computers, projectors, and Chromebooks—and all students own Android smartphones despite limited internet connectivity. Hence, developing an Android-based interactive multimedia resource was deemed essential to

enhance students' technical proficiency, increase engagement, and promote self-directed learning.

- **Learner characteristics analysis:** To tailor the multimedia application effectively, the research team examined the profile of prospective users: Grade 8 students aged approximately 12–14 years. At this developmental stage, learners often experience emotional sensitivity and fluctuating motivation, yet they possess a strong curiosity and are capable of systematic, concrete thought. These insights informed decisions about content complexity, interface design, and pedagogical strategies.
- **Educational technology analysis:** The team assessed the school's technological infrastructure to ensure it could support the proposed tool. Interviews and site visits confirmed that SMP Negeri 5 Satap Kombi has sufficient hardware (computers, laptops, projectors) and that all Grade 8 students possess Android phones. This environment is suitable for deploying an Android-based interactive multimedia application.

II. Design

During the Design phase, the researchers developed a detailed blueprint for the multimedia application. This involved defining the application's information architecture, user interface sketches, and functional requirements based on the Analysis findings.

III. Development

In the Development phase, the team translated design specifications into a working prototype. Key activities included:

- Creating storyboards to map out screens, interactions, and multimedia elements (e.g., text, images, videos, and practice exercises) related to the human circulatory system content.
- Implementing the prototype in Articulate Storyline 3. Once the interactive modules were completed, they were published in HTML5 format.
- Converting the HTML5 output into an Android application package (.apk) using Website 2 APK Builder Pro, enabling installation and offline use on students' Android devices.

IV. Implementation

Implementation constituted the fourth stage, during which the prototype was field-tested in a Grade 8 classroom at SMP Negeri 5 Satap Kombi. Students engaged with the multimedia application during regular science instruction. To assess usability, learners and their teachers completed structured questionnaires—using Likert-scale items—gauging practicality (kepraktisan) and overall user experience. Additionally, embedded formative quizzes within the application served as a measure of immediate learning, while a pre- and post-test design evaluated the product's instructional effectiveness.

V. Evaluation

The final Evaluation phase aimed to determine the completeness and quality of each development stage. Two types of evaluation were conducted:

- **Formative evaluation:** Iterative feedback was gathered at each stage (Analysis, Design, Development, Implementation) to refine the multimedia. Expert reviewers (including subject-matter specialists and instructional-media specialists with a minimum of a Master's degree in their respective fields) validated both content accuracy and media design.
- **Summative evaluation:** After full implementation, comprehensive data were collected to assess overall performance, learning outcomes, and user perceptions.
  - ***Performance:*** Experts evaluated the multimedia's design, content quality, pedagogical alignment, technical functionality, and user-friendliness.
  - ***Learning outcomes:*** Student performance on pre- and post-tests provided evidence of the application's effect on conceptual understanding and academic achievement.
  - ***Perception:*** Learner and teacher responses on questionnaires measured perceived utility, engagement, and satisfaction. This feedback guided final product adjustments.

Participants, data types, and data sources

Participants

- ***Learners:*** Grade 8 students at SMP Negeri 5 Satap Kombi comprised the primary user group for the multimedia application.
- ***Teachers:*** Science instructors who integrated the multimedia into their lesson plans provided data on practicality and classroom applicability.
- ***Expert validators:*** Content experts (master's-level science educators) and media specialists (master's-level instructional technologists) evaluated content validity and design quality.

Data classification

- ***Quantitative data:*** Numeric scores were collected from expert validation instruments (e.g., percentage of content validity, media validity), Likert-scale practicality questionnaires, and pre-/post-test results for learner performance.
- ***Qualitative data:*** Narrative feedback and open-ended responses from expert reviewers, teachers, and students informed iterative revisions and final product refinement (Gunawan, 2013).

Data sources

- **Teachers:** Provided curricular insights, classroom observations, and completed practicality questionnaires after small- and large-scale pilot tests.
- **Students:** Their responses to practicality questionnaires and performance on pre-/post-tests supplied data on user experience and learning effectiveness.
- **Expert validators/development team:** Their evaluations yielded content validity indices (CVI), media validity

indicators, and constructive feedback to improve instructional quality.

Data collection instruments

Questionnaires (Angket)

Questionnaires formed the primary instrument for data collection. According to Sugiono (2015:142), an angket is a tool consisting of written questions or statements to which respondents provide answers in a predetermined format. This study employed two types of closed-ended questionnaires:

- **Validation questionnaires:** Completed by subject-matter experts (for content accuracy) and media specialists (for design and usability) to calculate validity percentages for each item.
- **Practicality questionnaires:** Administered to teachers and students after pilot implementation to assess ease of use, clarity, engagement level, and overall practicality. These items used a five-point Likert scale (Strongly Agree = 5; Agree = 4; Somewhat Agree = 3; Disagree = 2; Strongly Disagree = 1).

Pre- and post-tests

Learners completed multiple-choice tests before and after using the multimedia application to measure conceptual understanding and knowledge retention. Scores ranged from 0 to 100, with a passing threshold set at 70% (the school's mastery standard). Pre-test and post-test data enabled calculation of learning gains (e.g., normalized gain scores).

Data analysis techniques

Qualitative data analysis

As described by Sugiono (2015:224), qualitative analysis involves systematically organizing data—such as interview transcripts, field notes, and expert feedback—into thematic categories, synthesizing information, and deriving insights for product refinement.

Quantitative data analysis

Quantitative data from validation and practicality questionnaires, as well as test scores, were analyzed statistically:

a) Validity analysis

The percentage score (P) was calculated for each questionnaire item using the formula:

P=∑(response×weight of each choice)n×highest weight×100 %P=n×highest weight∑(response×weight of each choice) ×100%

Where, *n* equals the total number of items. Products were then classified according to the achievement scale (adapted from Rengkuan, 2012, see Table 3.1):

- 90–100% : Very High (No Revision Needed)
- 75–89% : High (No Revision Needed)
- 65–74% : Moderate (Revision Recommended)
- 55–64% : Low (Revision Required)
- 0–54% : Very Low (Major Revision Required)

b) Practicality analysis

Practicability data were derived from Likert-scale responses.

Each respondent's mean score (*R*) was calculated using:

R=∑j=1nVijn×mR=n×m∑j=1nVij

Where, *V_{ij}* is the score given by the *j*th respondent on the *i*th criterion, *n* is the number of respondents, and *m* is the number of criteria. The overall mean for all respondents was then computed as:

Roverall=Total ScoreTotal RespondentsRoverall =Total RespondentsTotal Score

The resulting average was compared against the interval scale adapted from Supiyarto (2018) (see Table 3.2):

- 4.22–5.00 : Very Practical
- 3.41–4.21 : Practical
- 2.61–3.40 : Moderately Practical
- 1.80–2.60 : Less Practical
- 0–1.79 : Very Less Practical

c) Effectiveness analysis

Learner test scores were analyzed to determine instructional effectiveness. Each student's learning score (*S*) was calculated as:

$$S = \frac{T}{T_{\max}} \times 100$$

Where, *T* is the student's total score and *T_text max* is the maximum possible score (100). A score of ≥ 70 was considered mastery, in accordance with SMP Negeri 5 Satap Kombi's criteria. The percentage of students achieving mastery (*P*) was calculated as:

$$P = \frac{\text{Number of Students Mastered}}{\text{Total Number of Students}} \times 100\%$$

Instructional effectiveness was categorized based on Widoyoko (2014)

- $P > 80\%$: Highly Effective
- $60\% < P \leq 80\%$: Effective
- $40\% < P \leq 60\%$: Moderately Effective
- $20\% < P \leq 40\%$: Less Effective
- $P \leq 20\%$: Highly Less Effective

This comprehensive methodology ensured a systematic, evidence-based approach to designing, validating, and evaluating the Android-based interactive multimedia for integrated science learning.

3. Results & Discussion

Development outcomes

This research and development endeavor culminated in the creation of an interactive multimedia product in the form of an Android-based application designed to serve as an instructional medium, deployable on smartphones. The application integrates supportive content sourced from student textbooks, thereby aiming to enhance learners' comprehension of teacher-delivered subject matter. Specifically, this study focused on the human circulatory system, a key topic in the integrated science curriculum. The interactive multimedia product was developed using tools such as Articulate Storyline 3 and Website 2 APK Builder Pro, following the systematic ADDIE development model comprising five stages: Analysis, Design, Development, Implementation, and Evaluation (Sugiono, 2015).

Analysis phase

The analysis phase centered on identifying the necessity for developing the instructional media, grounded in observed pedagogical challenges. As outlined by Pribadi (2009) [32], this phase typically involves curriculum analysis, needs analysis, learner characteristics analysis, and educational technology analysis:

a) **Curriculum analysis**
The objective was to determine the curricular framework of the target institution. Based on observations and interviews with the vice principal and integrated science teachers at SMP Negeri 5 Satap Kombi, the school implements the Merdeka Curriculum for grades 7 and 8, and the K-13 Curriculum for grade 9.

b) **Needs analysis**
Classroom observations at SMP Negeri 5 Satap Kombi revealed a pronounced need for interactive multimedia learning tools. Traditional instruction has relied predominantly on printed textbooks and teacher-centered approaches, with limited availability of alternative media. Nevertheless, the school's infrastructure—comprising computers, LCD projectors, and Chromebooks—and the widespread use of Android smartphones among students provide a conducive environment for introducing Android-based interactive multimedia. Such an innovation is anticipated to enhance students' digital literacy, foster motivation, and support self-directed learning experiences.

c) **Learner characteristics analysis**
The research team analyzed the learner profile to inform the design of the multimedia application. The analysis focused on cognitive abilities, academic performance, motivation, attitudes, and process skills. Grade 8 students, aged approximately 12–14 years, were observed to exhibit emotional volatility and fluctuating learning motivation but also displayed high curiosity and the capacity for systematic thinking about concrete phenomena. These insights guided the development of multimedia content and instructional strategies.

d) **Educational technology analysis**
This analysis assessed the availability of technological resources necessary for implementing the developed multimedia. Interviews and observations confirmed that SMP Negeri 5 Satap Kombi possesses adequate equipment—including computers, laptops, LCD projectors—and that all Grade 8 students own personal Android smartphones. These conditions support the feasibility of deploying an Android-based interactive multimedia tool in the learning environment.

Design phase

The subsequent design phase involved planning and structuring the interactive multimedia application in accordance with insights gained from the analysis stage. Key activities included:

1. Preparation of development tools and materials

Essential tools and materials for the development phase included:

- **Computer/Laptop**
  The primary device used for product development was a Lenovo IdeaPad Slim 1i 14',7 with an Intel(R) Celeron(R) N4020 CPU, 4GB RAM, and a 64-bit operating system. Note: Higher-specification computers enhance development efficiency and effectiveness.
- **Articulate storyline**
  Articulate Storyline is an authoring tool that enables the integration of text, images, graphics, audio, animation, and video into interactive learning modules. The output formats include HTML5 and executable application files, compatible with various devices such as laptops, tablets, and smartphones. Articulate Storyline supports dynamic presentations aligned with instructional objectives, blending technical proficiency and artistic design to create engaging content. Its interface closely resembles Microsoft PowerPoint, making it accessible to educators familiar with PowerPoint, while also offering advanced features for more experienced users to develop highly interactive instructional media.
- **Website 2 APK Builder Pro**
  This tool converts web-based content into Android applications. In this project, PowerPoint presentations integrated with iSpring Suite 9 were transformed into Android-compatible applications using Website 2 APK Builder Pro, facilitating deployment on students' smartphones.

2. Development of the product interface

Following the design blueprint established through the flowchart and storyboard, the subsequent phase involved constructing the user interface for the Android-based interactive multimedia product. Initially, the researcher curated essential materials—including images, icons, animations, backgrounds, and other graphical assets—sourced from online repositories and adapted them to meet the specific requirements of the interactive multimedia application. These assets were then imported into Articulate Storyline 3, the primary development platform.

To ensure an engaging and aesthetically pleasing user experience, particular attention was given to color schemes and the optimal arrangement of graphical elements. This meticulous design approach aimed to sustain students' interest and prevent fatigue during their interaction with the multimedia product. The application also incorporated curated video content from YouTube, carefully aligned with the subject matter to reinforce students' understanding of the lesson content presented in the interactive module.

The interface development process encompassed several key elements:

- **Designing a custom logo:** Creating a unique logo to brand the application and enhance its visual identity.
- **Setting slide dimensions in articulate storyline 3:** The screen dimensions were adjusted to fit Android smartphone displays, employing a landscape orientation with a custom width of 970 pixels and a height of 546 pixels to optimize user experience (see Figure 4.1).
- **Designing interactive buttons:** Layouts and visual styling were carefully crafted to ensure intuitive navigation and functionality within the application.

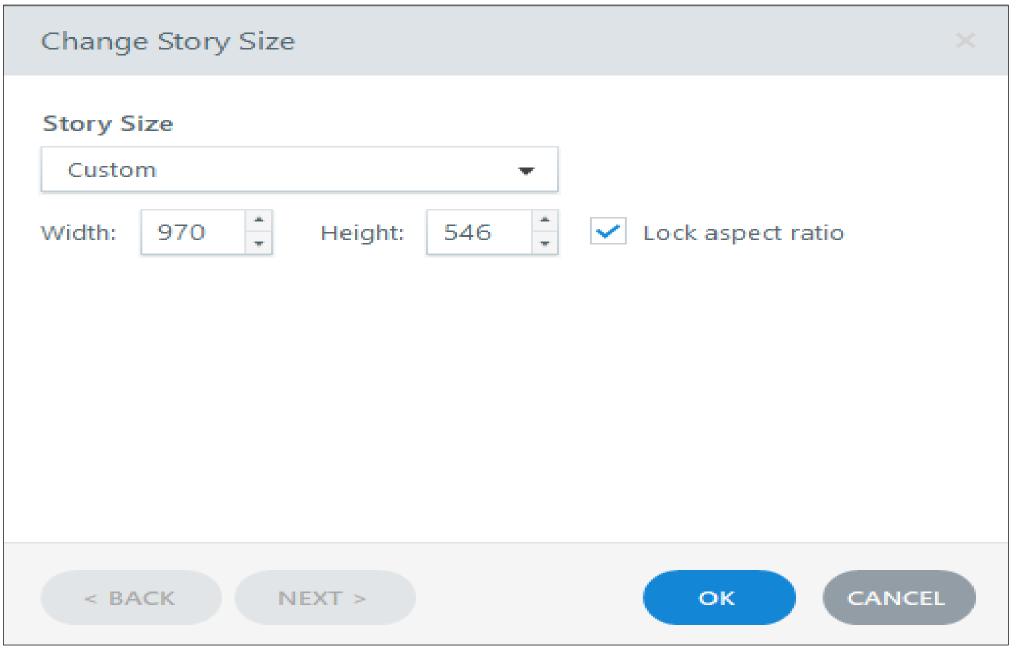

Fig 2: Display dimensions

Development phase

This phase focused on translating the design specifications into a fully operational interactive multimedia product. The Android-based application was intended to be accessible to both teachers and students via smartphone devices. The development steps undertaken included:

❖ **Prototyping the interactive multimedia application**

The development process commenced with assembling all previously prepared materials—such as images, animations, videos, and subject content—into a prototype structure using Articulate Storyline. This phase also entailed meticulous arrangement of these elements within the prototype interface to ensure coherence and usability. Subsequently, the researcher assigned interactive triggers to the designed buttons, enabling them to execute specific commands and display the desired content when activated.

Illustrates the home screen of the interactive multimedia application, designed to facilitate seamless user navigation to various instructional modules based on the learners' needs.

Fig 3: Initial screen display in the interactive multimedia

Fig 4: Menu page

❖ **Menu page development**

A structured main menu was developed to provide intuitive access to different sections of the application's content.

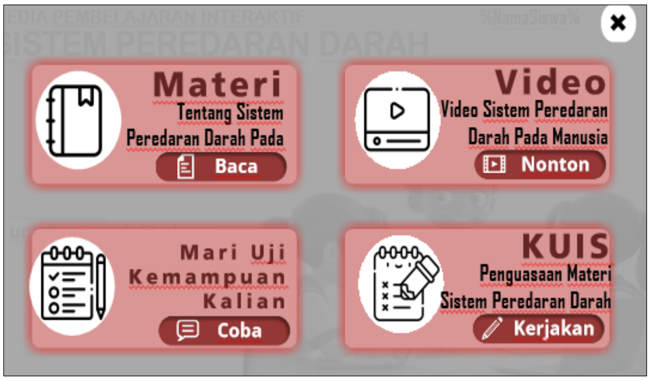

Fig 5: Menu list page

❖ **List menu page development**

The application also featured a list menu page, allowing learners to easily navigate through available topics and subtopics within the interactive module.

❖ **Prototype publishing**

Once the prototype achieved the desired functionality and design quality, it was exported and published in HTML5 format.

❖ **Conversion to .apk format**

To enable deployment on Android smartphones, the published HTML5 package was subsequently converted into an .apk file using Website 2 APK Builder Pro. This ensured compatibility and ease of installation on the intended devices.

Expert validation

At this stage, the developed interactive multimedia product underwent a rigorous validation process to determine its suitability for educational use. Validation served to assess and measure the appropriateness of the developed product prior to broader field testing. The validation was conducted by a subject-matter expert holding a doctoral degree (Ph.D.) in education. Two types of validation were performed: content validation and media validation. Feedback, including comments and suggestions, guided the researcher in refining the interactive multimedia tool.

Content validation

Content validation was conducted by an Expert who holds a bachelor's degree in Biology Education and possesses expertise relevant to the learning content embedded in the media. This process aimed to gather qualitative and quantitative data on the appropriateness and quality of the instructional content. Content validation was performed in two phases: the first on March 10, 2025, and the second on March 20, 2025. Table 4.1 summarizes the evaluation results for each criterion:

Table 1: Evaluation results from content expert

Statement	Phase 1	Phase 2
Clarity of text explaining concepts in the circulatory system through multimedia	4	5
Clarity of animations/images illustrating concepts in the circulatory system	4	5
Clarity of narration/audio for circulatory system concepts	3	5
Accuracy of concepts conveyed through text, animation, and narration	4	5
Completeness of learning content on the circulatory system	4	5
Appropriateness of multimedia use for circulatory system material	4	5
Student motivation to re-engage with multimedia content	4	5
Engagement of content and visuals (text and images)	4	4
Total	31	39

Based on these results, the average score after the first round was 3.86. The percentage of achievement was calculated using the following formula:

$$\text{Percentage} = \frac{\Sigma(\text{Score} \times \text{Weight})}{n \times \text{Max Weight}} \times 100\%$$

$$= \frac{(31 \times 1)}{(8 \times 5)} \times 100\% = 77.5\%$$

The expert evaluation yielded a 69% achievement score, placing the product in the "moderately high" qualification category, indicating that the product required revisions. The expert suggested aligning the content more closely with learning objectives, specifying the number of meetings required, synchronizing video materials, and clarifying lesson objectives.

After revising the product according to these recommendations, a second round of content validation was performed. The subsequent score average was 4.89, with an achievement percentage of 97.5%, placing the product in the "high" qualification category—indicating that the product was suitable for use without further revisions.

Media expert validation

Validation of the media design and instructional approach was carried out by a specialist with a Master's and Doctorate in Educational Technology. She holds expertise in instructional media design and curriculum development. The media validation was also conducted in two phases: March 12 and March 22, 2025. Table 4.2 presents the evaluation results:

Table 2: Evaluation results from media expert

Statement	Phase 1	Phase 2
Appropriateness of hardware selection (computers, projectors, speakers)	4	4
Appropriateness of software tools (iSpring, Autoplay, Camtasia)	4	5
Effectiveness of media devices in achieving learning objectives	5	4
Suitability of multimedia for circulatory system instruction	4	4
Appropriateness of multimedia in supporting circulatory system content	4	4
Potential of multimedia to facilitate learning content	4	5
Clarity of visual components (text, images, animation, video)	3	4
Clarity of audio components (narration, music, sound effects)	3	3
Coherence of images, text, and color	3	5
Sequence of multimedia presentation	2	3
Ease and speed of multimedia access	2	5
User-friendliness of multimedia operation	2	4
Time efficiency (learning speed) of multimedia	2	5
Visual representation in multimedia	3	5
Audio representation in multimedia	3	3
Arrangement of images, text, and colors	3	4
Engagement level of multimedia	3	5
Appeal of multimedia delivery strategy	3	5
Multimedia's motivational capacity	4	5
Visual appeal (text, images, animation, video)	4	5
Audio appeal (narration, music, sound effects)	4	4
Layout appeal (image, text, color)	2	5
Total	64	96

In the first phase, the average score was 2.91, yielding an achievement percentage of 58.2%, categorized as "moderately low," indicating that the product was unsuitable and required revisions. The media expert recommended improving accessibility, aligning duration with lesson time, enhancing the visual presentation of learning objectives, and increasing the creativity of content presentation.

Following revisions, the second round of media validation yielded an average score of 4.36, with an achievement percentage of 87%, placing the product in the "high" qualification category—indicating that the product was appropriate and required no further revisions.

Implementation phase

In the implementation phase, the researcher tested the product's practicality and effectiveness with learners.

- **Small-group trial**
  Conducted on April 14, 2025, with four students representing varying ability levels. Results indicated high usability and ease of use. Student responses yielded an average score of 4.6, placing the product in the "very practical" category.
- **Large-group trial**
  Conducted on April 21, 2025, with nine Grade 8 students. Learners interacted independently with the multimedia, showing enthusiasm and proficiency. Questionnaire responses averaged 4.4, confirming the product's "very practical" classification.

Effectiveness testing

Students completed an embedded test within the multimedia.

Scores ranged from 70 to 100, with an average of 85, classifying the product as "effective."

Evaluation phase

Evaluation was conducted throughout each phase to ensure continuous improvement. During the analysis stage, curriculum, needs, learner characteristics, and technology were assessed. During the design stage, materials were aligned with the multimedia interface. The development stage produced the product using the identified tools and materials. Expert validation was then conducted, followed by implementation testing. Evaluation also occurred at the end of each stage to guide revisions and finalize the product.

Discussion

The developed interactive multimedia learning product

The interactive multimedia product developed in this study is a computer-based instructional medium that integrates multiple sensory components. It features an application-based format accessible via computers without requiring an internet connection. The multimedia product includes elements such as text, images, animations, videos, and audio, seamlessly integrated to produce an engaging and effective learning tool. Students can use the product independently (self-paced learning) or under teacher guidance (guided learning), making it particularly suitable for junior high school students, who are typically in their early adolescence.

The initial screen or "Login Page" uses a white background to evoke purity of thought and action, as well as a sense of freshness and calmness (Cabarga, 2003). The main title "HUMAN CIRCULATORY SYSTEM" is presented in uppercase letters using the Goudy Stout font, chosen for its high readability and clarity, with black letters that evoke strong emotions and intellectual stimulation (Cabarga, 2003). The black text strongly contrasts with the white background, drawing students' attention. This title is also emphasized using bold formatting, and it is complemented by a friendly, smiling animation of blood, predominantly red in color, intended to enhance enthusiasm and energy (Cabarga, 2003). Collectively, the combination of color, shape, and visuals aims to provide students with a stimulating, emotionally engaging, and dynamic learning experience.

The main interface presents four interactive buttons that change color when clicked, each representing a core subtopic to introduce students to the learning material within the interactive multimedia. Background music incorporated into the application aims to increase enthusiasm and sharpen focus. Each category is labeled using the Matura MT Script Capitals font, selected for its clarity and legibility. The available categories include: "Blood Cells," "Circulatory Organs," "Circulatory Mechanisms," "Blood Flow & Pressure," and "Circulatory Disorders." Each category directs users seamlessly to its respective page through embedded interactive links.

Selecting a category takes the user to the relevant material, with the home screen also featuring a "Next" button to guide students through the multimedia experience systematically. The subsequent page includes an introductory video with accompanying narration that greets users and provides a brief overview of the learning objectives. Following this, a page outlines the learning objectives, with the Basic Competencies and Indicators presented in Goudy Old Style 16pt font—chosen for its readability and consistency with the overall design. Navigation buttons—Home (house icon), Back (left arrow), and Next (right arrow)—facilitate movement between sections. Progressing further, the Indicators page outlines the intended learning outcomes. The content page presents five subtopics and an animated GIF of an insect holding an "Attention" sign, with accompanying narration to direct student focus. Red is used for the subtopic buttons to maintain design consistency, while the blue background fosters calmness and concentration (Cabarga, 2003). The "CONTENT" heading is presented in black, capitalized letters to emphasize its significance, with a Home button at the top left for easy navigation.

Each topic integrates various multimedia components—text, images, videos, audio, and animations—to align with the concepts being studied. Video and animation elements are incorporated to visualize abstract or microscopic aspects of blood cells and circulatory organs, helping students understand complex content through simplified graphical representations.

After completing the learning modules, students proceed to the quiz section. The quiz heading, labeled "QUIZ," uses Goudy Stout font in bold for high visibility. The quiz comprises 10 questions presented in a circular format, each corresponding to the relevant category. Students are guided to select answers using a drop-down box, with a "Next" button to proceed. Students are encouraged to choose carefully but may return to previous questions using the "Back" button. Upon completion, selecting "Done" triggers a pop-up displaying test results, including the score and a pass/fail notification (75% minimum for passing). This pop-up also lists student answers alongside correct responses for review. An "OK" button allows users to exit, while a "Print" option enables students to print their results for record-keeping.

The final section is the "Author" page, where "AUTHOR" is displayed in uppercase, bold red letters. Author details are presented in Algerian 88pt for headings and Aharoni 24pt white text against a black background—chosen for its association with potential and possibilities (Cabarga, 2003). This page encourages exploration, underscoring the potential impact of the learning module.

The developed interactive multimedia was packaged as an Android .apk file, enabling easy distribution and offline access. Before packaging, all components were assembled and refined using Articulate Storyline 3, incorporating icons, audio, images, and videos. This content was then converted into an Android-compatible format using Website 2 APK Builder Pro, ensuring seamless access without requiring an internet connection.

This integration process required precision and technical expertise, as software or human errors could delay development. These challenges were mitigated through independent learning and resourceful problem-solving.

The interactive multimedia serves as an instructional strategy designed to foster student engagement and motivation, aligning with Asyhar's (2012) [5] classification of instructional media functions:

- **Learning resource:** Multimedia empowers students to construct new knowledge about the circulatory system.
- **Semantic function:** Multimedia clarifies abstract ideas, making concepts more tangible and understandable.
- **Manipulative function:** Multimedia enables dynamic representations of blood cell structures and circulatory organs.
- **Distributive function:** The product can reach unlimited learners, increasing efficiency and accessibility.
- **Psychomotor function:** Multimedia enhances students' observational and technological skills.
- **Psychological function:** Multimedia captures attention, evokes emotions, and stimulates cognitive engagement, promoting creativity and sustained interest.

Expert evaluations confirmed the product's validity, practicality, and effectiveness, both in terms of media design and learning content. The validation process included two rounds of content and media reviews by subject matter experts. Data were collected through questionnaires and expert feedback from teachers and students. A five-point scale—ranging from "Very Good" (5) to "Very Poor" (1)—was employed to calculate mean scores and percentages, which determined the product's validity and practicality.

Validity, practicality, and effectiveness of the android-based interactive multimedia for science education in junior high schools

a) Product validity

Prior to implementation, the product underwent expert validation to determine its feasibility. According to Chan & Budiono (2019:173), validation assesses product viability before field testing. Two rounds of content validation yielded mean scores of 3.86 (69%—"moderately high," needing revision) and 4.89 (87%—"high," no revision needed). Media validation yielded initial scores of 2.91 (58.2%—"moderately low," requiring revision) and 4.36 (87%—"high," no revision needed). These results confirm the product's overall validity for implementation.

b) Product practicality

Following validation, product trials were conducted to assess practicality. According to Kumalasani (2018:6), a product is considered practical if learners find it easy to use in a real-world setting. Both small-group (average score 4.6) and large-group trials (average score 4.4) yielded "very practical" ratings, indicating the product's usability. Consequently, the Android-based interactive multimedia developed using iSpring Suite is both valid and practical for educational use.

c) Product effectiveness

Effectiveness was determined through integrated assessments embedded within the multimedia module. Student scores from the test (average 85) exceeded the passing criterion, placing the product in the "effective" category, signifying that the developed multimedia product successfully enhanced learning outcomes.

4. Conclusions

Based on the results of the development research and subsequent discussions, several key conclusions can be drawn: The developed product, an Android-based Interactive Multimedia application, offers students an engaging experience that enables independent learning while taking advantage of accessible and user-friendly features within the application. This Interactive Multimedia product was designed as an instructional medium for science education, specifically addressing learning objectives related to the human circulatory system. It integrates initial learning components such as prior knowledge activation, learning objectives, core instructional activities, formative assessments, and includes videos as well as concluding activities involving evaluation exercises. The Android-based Interactive Multimedia product has been validated as an effective learning medium through expert evaluations involving content and media experts, achieving an overall validity percentage of 87%. Additionally, the product has successfully passed assessments for both practicality and efficiency, confirming its suitability for use as a science learning tool.

References

1. Adhitama HY. Pengembangan multimedia pembelajaran interaktif pada materi rangka dan otot manusia untuk meningkatkan kemandirian belajar peserta didik SMP kelas VIII [Skripsi]. Yogyakarta: Pendidikan IPA FMIPA Universitas Negeri Yogyakarta, 2015.
2. Aqib Z. Model-model, media, dan strategi pembelajaran kontekstual. Bandung: CV. Yarma Widya, 2007.
3. Ariwibowo P, et al. Pengembangan audio visual sistem sirkulasi darah berpendekatan saintifik. Jurnal USEJ, 2014, 4(2).
4. Arsyad A. Media pembelajaran. Jakarta: PT Raja Grafindo Persada, 2011.
5. Asyhar R. Kreativitas mengembangkan media pembelajaran. Jakarta: Referensi, 2012.
6. Arsyad A. Media pembelajaran. Jakarta: PT Rajawali Press, 2011.
7. Budiningsih A. Belajar dan pembelajaran. Yogyakarta: Rinika Cipta, 2004.
8. BSNP. Permendiknas No. 22 tahun 2006 tentang standar isi untuk satuan pendidikan dasar dan menengah. Jakarta: Depdiknas, 2006.
9. Campbell N, et al. Biologi jilid I edisi 8. Jakarta: Erlangga, 2008.
10. Dimyati, Mudjono. Belajar dan pembelajaran. Jakarta: Rineka Cipta, 2009.
11. Heinich R, et al. Instructional media and technologies for learning. 7th ed. New Jersey: Merrill Prentice Hall, 2002.
12. Kahar S, Tumbel F, Paat M. The effect of environmental learning models on science process skills and learning

outcomes of students in SMP Negeri 10 Manado. Int J Acad Res Dev. 2020;5(4):34–8.
13. Kawuwung FR, Paat M. Analisis angket tanggapan siswa terhadap implementasi perangkat pembelajaran biologi SMA Kabupaten Minahasa Utara. Seminar Nasional Biologi Kepulauan, 2018, 1.
14. KBBI. Kamus besar bahasa Indonesia: Pengertian interaktif [Internet], 2017 [cited 2025 Feb 5]. Available from: http://kbbi.web.id/pusat
15. Kindangen CR, Paat M, Suryani NW, Rungkat JA. Pengembangan multimedia interaktif menggunakan model problem based learning pada mata pelajaran IPA kelas VIII SMP Katolik Kembes. SOSCIED. 2023;6(2):361–72.
16. Lelamula MD, Sasinggala M, Paat M. Pengaruh model pembelajaran problem based learning dengan media berbasis PowerPoint di masa pandemi Covid-19 terhadap hasil belajar siswa pada pembelajaran IPA biologi di SMP. SCIENING. 2022;3(1):22–7.
17. Mokalu YB, Paat M, Lihiang A, Tumbel FM. Buku Ajar IPA 3. Manado: Penerbit Lakeisha, 2023.
18. Mokalu YB, Paat M, Wowor EC, Tumewu WA, Kawuwung FR. Students' learning interest in the implementation of project-based learning models. SOSCIED. 2023;6(2):610–9.
19. Munandi Y. Media pembelajaran: Sebuah pendekatan baru. Jakarta: Gaung Persada (GP) Press, 2008.
20. Munandi Y. Media pembelajaran. Jakarta: Referensi Gaung Persada (GP) Press, 2013.
21. Munir. Kurikulum berbasis teknologi informasi dan komunikasi. Bandung: Alfabeta, 2010.
22. Nuh M. Ilmu pengetahuan alam SMP/MTs kelas VIII semester II. Jakarta: Kementerian Pendidikan dan Kebudayaan, 2014.
23. Onsu M, Sumampouw HM, Paat M. Development of an e-module on movement and style material using Canva to improve learning outcomes and retention in independent curriculum driving schools. Int J Adv Educ Res. 2023;8(4):30–5.
24. Paat M. Implementasi multimedia pembelajaran biologi berbasis model PBL melalui Google Classroom di Jurusan Pendidikan Biologi UNIMA. J Ilm Mandala Educ. 2022;8(3):2551–7.
25. Paat M, Mokalu YB. Development of web-blog-based learning media using problem-based learning model. SOSCIED. 2023;6(2):505–13.
26. Paat M, Mokalu YB. Pelatihan pembelajaran berbasis daring melalui metode interaktif di Desa Pineleng, Kabupaten Minahasa. Madaniya. 2023;4(3):1185–92.
27. Paat M, Sompotan AF, Pesik A, Mokalu YB, Moroki I. Penerapan multimedia pembelajaran berbasis masalah dalam meningkatkan hasil belajar dan keterampilan berpikir tingkat tinggi. J Pendidikan MIPA. 2024;14(1):155–62.
28. Paat M, Sutopo H, Siregar N. Developing a mobile multimedia-based learning resource on living of komodo dragons. In: Proc 2019 3rd Int Conf Comput Sci Artif Intell, 2019, p273–7.
29. Paat M, Sutopo H, Siregar N. Developing augmented reality application on komodo dragon for elementary school children during the new normal of COVID-19 pandemic. J Theor Appl Inf Technol. 2021;99(11):2761–9.
30. Patibang RT, Paat M, Rungkat JA, Warouw ZWM, Rampengan M, Mokalu YB. Pemanfaatan media pembelajaran audio visual menggunakan aplikasi Capcut untuk meningkatkan motivasi belajar siswa SMP pada materi sistem pencernaan manusia: Penelitian. J Pengabdi Masyarakat Riset Pendidikan. 2025;3(4):2981–8.
31. Pertiwi MG, Lihiang A, Paat M. Development of Animaker-based science learning multimedia on global warming materials at SMP Brother Don Bosco Tomohon. Web Semant. 2023;2(6):166–74.
32. Pribadi BA. Model desain sistem pembelajaran. Jakarta: Dian Rakyat, 2009.
33. Putra A. Pengembangan multimedia pembelajaran biologi berbasis information and communication technology (ICT) pada materi virus [Skripsi]. Manado: Universitas Negeri Manado, 2014.
34. Putri R. Pengaruh kebijakan perubahan kurikulum terhadap pembelajaran di sekolah. Padang: Universitas Negeri Padang, 2019, p1–9.
35. Purjiyanta E, et al. IPA terpadu, jilid 1 kelas VIII SMP. Jakarta: Gelora Aksara Pratama, 2014.
36. Rengkuan M. Identifikasi variasi gen hormon pertumbuhan sapi peranakan Ongole di Balai Besar Inseminasi Buatan Singosari dan Perusahaan Daerah Pasuruan sebagai media pembelajaran materi pengenalan teknik analisis biologi molekuler [Disertasi]. Malang: Universitas Negeri Malang, 2012.
37. Rosang GG. Pengembangan multimedia berbasis komputer pada pokok bahasan hereditas di SMA [Skripsi]. Manado: Universitas Negeri Manado, 2015.
38. Sadiman A, et al. Media pendidikan: Pengertian, pengembangan, dan pemanfaatannya. Jakarta: Rajawali Pers, 2009.
39. Sanjaya W. Strategi pembelajaran berorientasi standar proses pendidikan. Jakarta: Kencana, 2010.
40. Sanudin TN, Paat M, Tumbel FM. Development of cooperative learning by utilizing circular design on the subject of energy at SMP Negeri 13 Manado. Int J Adv Educ Res. 2023;8(4):56–60.
41. Silangen IRC, Lihiang A, Paat M. Pengembangan aplikasi berbasis Android sebagai media pembelajaran biologi pada materi virus di SMA Negeri 3 Manado. JSPB BIOEDUSAINS. 2024;5(2):132–41.
42. Siregar N, Sutopo H, Paat M. Mobile multimedia-based Batakologi learning model development. J Mobile Multimedia. 2019;15(4):271–88.
43. Sondakh RY, Tumbel FM, Paat M, Poluakan C. Developing Android application-based interactive learning media with offline mode on excretion system materials at the Hati Kudus Yesus Catholic Junior High School Kroit. Int J Educ Res Dev. 2021;3(3):8–13.

44. Sugiyono. Metode penelitian pendidikan: Pendekatan kualitatif, kuantitatif, dan R&D. Bandung: Alfabeta, 2014.
45. Sugiyono. Metode penelitian dan pengembangan (Research and Development/R&D). Bandung: Alfabeta, 2015.
46. Suparno P. Teori perkembangan kognitif Jean Piaget. Yogyakarta: Kanisius, 2011.
47. Supiyarto. Media Barungca-5-1 pada materi sifat-sifat cahaya dalam model pembelajaran problem based learning di kelas V sekolah dasar. J Pendidikan Guru Sekolah Dasar, Universitas Jambi, 2018.
48. Tangdilian J, Tumbel FM, Paat M. Pengembangan media pembelajaran biologi model problem based learning kelas X di SMA Negeri 3 Manado. JSPB BIOEDUSAINS. 2023;4(2):119–25.
49. Tampinongkol NN, Paat M, Lihiang A. Pengembangan media audio visual dengan model problem based learning (PBL) berbasis kearifan lokal Sulawesi Utara pada pembelajaran biologi di SMA. JSPB BIOEDUSAINS. 2022;3(2):136–43.
50. Tumbel FM, Mokosuli YS, Paat M. Application of project based learning insect characteristics around Lake Tondano in entomology course. J Biol Tropis. 2022;22(1):81–7.
51. Tumanding N, Lihiang A, Paat M. Development of multimedia-based science learning teaching materials using problem-based learning models on environmental pollution materials. Int J Formal Educ. 2023;2(11):359–71.
52. Warsita B. Teknologi pembelajaran: Landasan dan aplikasinya. Jakarta: Rineka Cipta, 2008.
53. Watung F. Pengembangan jaringan offline sebagai media pembelajaran pada materi substansi genetika [Skripsi]. Manado: Universitas Negeri Manado, 2016.
54. Wibawanto W. Desain dan pemrograman multimedia pembelajaran interaktif. Jawa Timur: Penerbit Cerdas Ulet Kreatif, 2017.
55. Widayat W, et al. Pengembangan multimedia interaktif sebagai media pembelajaran IPA terpadu pada sistem gerak pada manusia. Jurnal USEJ, 2014, 3(2).
56. Winaryati E. Evaluasi supervisi pembelajaran. Yogyakarta: Graha Ilmu, 2014.
57. Winataputra US. Hakikat belajar dan pembelajaran, 2014.