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Development of Android-Based Smart Learning Media for the Operating Systems Course Using the ADDIE Model

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ABSTRACT

Purpose – The rapid advancement of digital technology has encouraged higher education institutions to integrate innovative learning media to enhance the quality of the teaching and learning process. However, learning activities in Operating Systems courses are still predominantly conducted using conventional methods, causing students to experience difficulties in understanding abstract concepts such as process management, memory management, CPU scheduling, and file systems. This study aims to develop Android-Based Smart Learning media for the Operating Systems course and to determine the feasibility level of the developed media as an interactive learning tool.

Method – This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The developed product was validated by subject-matter and media experts before being implemented with students of the Informatics and Computer Engineering Education Program who were enrolled in the Operating Systems course. Data were collected through validation sheets and student response questionnaires using a five-point Likert scale and analyzed using descriptive quantitative methods.

Results – The findings indicate that the Android-Based Smart Learning media was successfully developed by integrating learning materials, instructional videos, interactive quizzes, and automated feedback features into a single Android application. The material expert validation yielded a score of 89.00%, while the media expert validation achieved a score of 90.00%, both categorized as highly feasible. Furthermore, student responses obtained an average percentage of 90.27%, classified as very good. Therefore, the developed media was considered suitable for supporting the learning process in the Operating Systems course.

Research Implications – This study was limited to a single study program and Android devices; therefore, the generalizability of the findings is limited.

Originality – This research integrates the concepts of mobile and smart learning into a single interactive learning medium specifically designed to support Operating Systems education in higher education institutions.

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INTRODUCTION

Background of the Study

Advancements in information and communication technology have significantly changed various aspects of human life, including education. Digitalization has encouraged universities to integrate technology into teaching and learning practices to improve educational quality and prepare graduates to adapt to technological advancements in the era of Industry 4.0 and Society 5.0. The use of technology in education now serves not only as a tool for delivering information but also as a medium for creating more interactive, flexible, and student-centered learning experiences. Consequently, lecturers are required to develop innovative learning approaches that accommodate the characteristics of the digital generation, which is highly familiar with technological devices, particularly smartphones [1].

One technology with considerable potential to support learning is the Android-based mobile device. Android is the most widely used operating system for smartphones because of its open-source nature, ease of development, and support for a wide range of interactive multimedia applications. The widespread use of smartphones among university students presents an opportunity to develop mobile-learning-based educational media. Mobile learning enables students to access learning materials at any time and place without being constrained by time and location. Numerous studies have shown that Android-based learning media can enhance learning motivation, student engagement, and instructional effectiveness by providing a more flexible and personalized learning experience [2], [3]. Furthermore, the development of Android-based e-modules has proven effective as an alternative for supporting distance learning [4].

Over time, the concept of mobile learning has evolved into smart learning, an educational approach that utilizes digital technology in an adaptive, interactive, and contextual manner to facilitate more effective learning. Smart learning enables students to gain richer learning experiences through the integration of multimedia content, instructional videos, automated assessments, instant feedback, and real-time access to learning resources [5], [6]. The implementation of smart learning is particularly relevant in higher education because it supports self-directed learning and enhances student engagement during the learning process.

One course that requires the support of interactive learning media is Operating Systems. This course is a core subject in the Informatics and Computer Engineering Education Program and covers various fundamental concepts, including operating system structures, process management, memory management, CPU scheduling, file systems, process synchronization, system security, and virtualization. These topics are highly complex because they primarily involve abstract internal computer mechanisms that are difficult for students to directly observe [7].

Based on preliminary observations of the Operating Systems learning process, it was found that instruction is still predominantly conducted through traditional lectures and PowerPoint-based presentations. Although these methods are effective for delivering theoretical content, students continue to experience difficulties in understanding abstract concepts, such as CPU scheduling, memory management, and process synchronization. Furthermore, the limited availability of interactive learning media results in lower student participation and challenges in independent learning. This situation has contributed to reduced learning motivation and an inadequate understanding of key operating system concepts.

Literature Review

Android-based learning media have been widely developed and proven effective in improving educational quality through engaging, interactive, and accessible content delivery. A study conducted by Wulandari et al. revealed that Android-based learning media developed using the ADDIE model demonstrated high levels of validity and practicality and significantly enhanced students' learning activities [8]. Similarly, Imamah and Hasanah found that Android-based e-modules were effective learning tools because they improved students' learning motivation and independent learning abilities [9].

Furthermore, a systematic review by Crompton and Burke demonstrated that the use of mobile devices in education positively affects student engagement, learning flexibility, and academic achievement compared with conventional instructional approaches [10]. These findings reinforce the view that integrating mobile technology into education can create a more effective learning environment that aligns with the needs of learners in the digital age.

From the perspective of Multimedia Learning Theory, Mayer argues that the combination of text, images, audio, animation, and video enhances conceptual understanding because it engages multiple cognitive channels during the learning process [1]. Therefore, the implementation of smart learning, which integrates various multimedia components, has the potential to improve learning quality, particularly in courses characterized by a high level of abstraction, such as Operating Systems.

Furthermore, the effectiveness of digital learning media is supported by the Cognitive Load Theory, which suggests that well-designed instructional materials delivered through mobile devices can reduce unnecessary cognitive load, thereby facilitating information retention and improving learning efficiency [11]. In the context of higher education, the use of integrated smart learning platforms enables adaptive and personalized learning experiences, which have been shown to significantly increase students' active participation compared to traditional face-to-face lecture methods [12].Therefore, implementing a smart learning approach that integrates various multimedia components has the potential to enhance learning quality, particularly in courses characterized by a high level of abstraction, such as Operating Systems.

Research Gap

Although numerous studies have developed Android-based learning media, most have focused on secondary school subjects, science education, language learning, and introductory programming courses [8], [9]. Research specifically aimed at developing Android-based learning media using a smart learning approach for Operating Systems courses in higher education remains relatively limited.

In addition, most existing learning media primarily focus on presenting digital content and simple assessments without comprehensively integrating smart learning features, such as instructional videos, interactive evaluations, automated feedback, and mobile-based self-learning access. However, the complex and abstract nature of operating system concepts requires learning media capable of visualizing concepts and providing a more interactive learning experience.

Based on these conditions, a gap exists between students' needs for flexible, interactive, and easily accessible learning media and the limited availability of learning media specifically designed for operating system courses. This gap forms the basis for the development of Android-Based Smart Learning media for operating system education.

Theoretical Framework

This study is based on the assumption that the integration of Android technology with a smart learning approach can provide a solution to the challenges encountered in operating system education. The integration of digital learning materials, instructional videos, interactive exercises, automated assessments, and immediate feedback within a single Android application enables students to experience a more flexible, engaging, and digitally relevant learning environment than traditional methods.

The development of Android-Based Smart Learning media is also supported by the Multimedia Learning Theory, which suggests that learning becomes more effective when information is presented through a combination of multiple media formats rather than through text or lectures alone [1]. Furthermore, the smart learning approach allows students to learn independently according to their individual needs and learning pace, thereby enhancing their motivation and conceptual understanding.

Research Objectives

This study aims to:

1. Develop Android-based Smart Learning media for the Operating Systems course using the ADDIE model.
2. The feasibility level of the developed media was determined based on evaluations by subject-matter and media experts.
3. Examine students' responses toward the use of Android-Based Smart Learning media in operating system learning.

Product Hypothesis

The product hypothesis of this study is that the developed Android-Based Smart Learning media meets the criteria of validity, practicality, and feasibility for use as a learning medium in the Operating Systems course. The media is considered feasible if it achieves a minimum evaluation score of 82% from subject matter experts, media experts, and student users.

METHOD

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) proposed by Branch [13]. The ADDIE model was selected because it provides a systematic, flexible, and widely adopted framework for developing technology-based learning media. The product developed in this study was an Android-based Smart Learning application for the Operating Systems course, designed to support both independent learning and classroom instruction.

Figure 1. ADDIE Model

1. The Analysis phase served as the initial stage aimed at identifying the needs and challenges encountered in the teaching and learning process of the Operating Systems course. Data were collected through observations, interviews, and document analyses of existing instructional practices.

Activities conducted during this phase included: (a) analysis of students' learning needs; (b) analysis of user characteristics; (c) Analysis of Course Learning Outcomes (CLOs); (d) Analysis of Operating Systems course materials; and (e) analysis of previously utilized learning media.

The results indicated that students experienced difficulties in understanding abstract topics, such as process management, memory management, CPU scheduling, and file systems. Furthermore, the learning media used were limited to presentation slides and printed modules, highlighting the need for more interactive, flexible, and mobile-accessible media.

2. The Design phase was conducted based on the findings obtained during the needs analysis. During this stage, the learning media were planned from both a content and technical perspective.

The activities included: (a) designing the system flowchart, (b) use case diagram, (c) class diagram, (d) preparing learning materials, and (e) designing research instruments for product validation and evaluation.

The application design emphasized user-friendliness, visual consistency, ease-of-navigation, and multimedia integration. In addition, the main features of the application were determined, including (a) Course Syllabus, (b) Semester Learning Plan (RPS), (c) Learning Materials, (d) Learning Videos, (e) Interactive Exercises, (f) Evaluation Module, and (g) Developer Information.

The output of this phase was a comprehensive blueprint that served as the foundation for subsequent development.

System Flowchart

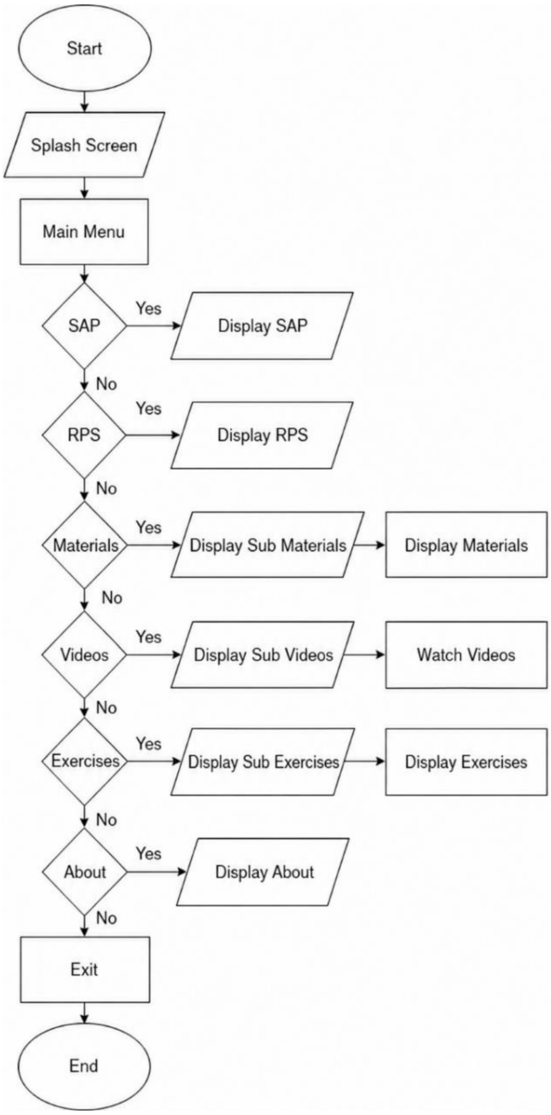

Figure 2. System Flowchart

The system flowchart illustrates the operational workflow of the Android-Based Smart Learning application, beginning from the moment users launch the application until they access the available features. This flowchart serves as a development guideline by depicting relationships among menus and navigation pathways within the application

Usecase Diagram

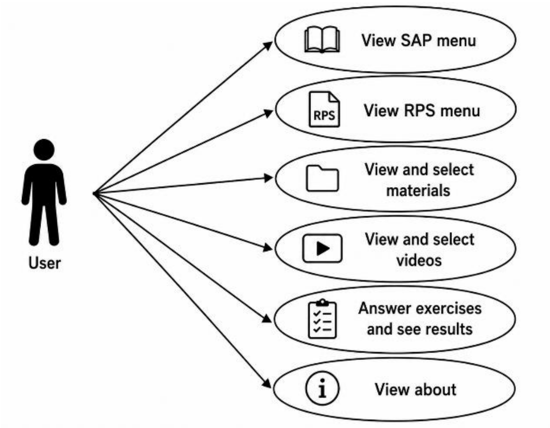

Figure 3. Use Case Diagram

The Use Case Diagram describes the interactions between users and the Android-Based Smart Learning system for the Operating Systems course. The diagram illustrates the primary functions accessible to users and the relationship between users and system features.

Class Diagram

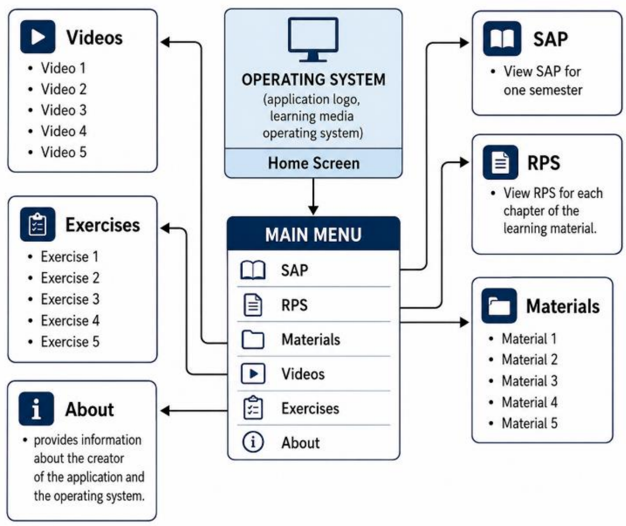

Figure 4. Class Diagram

The Class Diagram represents the structural design of classes within the Android-Based Smart Learning application and illustrates the relationships among classes. It identifies the attributes and methods associated with each class, thereby facilitating the design and development processes.

3. During the Development phase, the Android-Based Smart Learning application was constructed based on the design specifications produced in the previous stage. Learning materials, videos, images, animations, and other multimedia components were integrated into the Android application to create a fully functional product.

After the development was completed, the product underwent validation by subject-matter and media experts. The validation process evaluated content quality, instructional design, visual appearance, Navigation; Interactivity; and Technical performance.

Feedback and recommendations provided by the validators were used to revise and improve the application before implementation.

4. The Implementation phase involved testing the Android-based Smart Learning application with students enrolled in the Operating Systems course. During this stage, the students used the application throughout the learning process and explored all available features.

Subsequently, the students were asked to evaluate the application using a user-response questionnaire. The collected data were used to assess (a) practicality, (b) ease of use, (c) attractiveness, and (d) user acceptance of the developed learning media.

5. The Evaluation phase aimed to assess the overall quality of the developed product based on expert validation results and user feedback. Evaluation was conducted both formatively throughout each development stage and summatively after its implementation. The evaluation results were used to identify product weaknesses and perform final revisions, resulting in an Android-based Smart Learning application that was valid, practical, and suitable for use in the Operating Systems course. Furthermore, the evaluation served as the basis for determining whether the development objectives were successfully achieved.

Participants

The participants in this study consisted of subject-matter expert validators, media expert validators, and student users of the learning media. The subject-matter expert validators consisted of two lecturers with expertise in Operating Systems and a minimum of three years of teaching experience. The media expert validators consisted of two lecturers specializing in educational technology and digital learning media development. The student participants were undergraduate students enrolled in the Informatics and Computer Engineering Education Program who were currently taking or had previously completed the Operating Systems course.

Population and Sampling Technique

The population comprised all students in the Informatics and Computer Engineering Education Program enrolled in the Operating Systems course during the academic year in which this study was conducted. A purposive sampling technique was employed, whereby participants were selected based on specific criteria relevant to the study objectives. The field testing involved 30 students who met the eligibility requirements. Students were included in the study if they were actively enrolled as university students, were currently taking or had completed the Operating Systems course, owned an Android-based smartphone, and were willing to participate in all stages of the research.

Research Instruments

Three instruments were employed in this study: the subject-matter expert validation sheet, media expert validation sheet, and student response questionnaire. A subject-matter expert validation sheet was used to evaluate the quality of the instructional content included in the learning media. The assessment aspects included content relevance, concept accuracy, content completeness, evaluation appropriateness, language, and presentation quality.

A media expert validation sheet was used to evaluate the quality of the developed learning media. The assessment aspects included user interface design, navigation usability, media interactivity, visual consistency, and software engineering. A student response questionnaire was used to measure user acceptance of the learning media. The assessment aspects included ease of use, media attractiveness, clarity of instructional content, learning motivation and user satisfaction.

Data were collected using a five-point Likert scale ranging from Strongly Disagree to Strongly Agree [14].

Table 1. Likert Scale Response Categories

Score	Response Category
1	Strongly Disagree (SD)
2	Disagree (D)
3	Neutral (N)
4	Agree (A)

Instrument Validity and Reliability
Content validity was established through expert judgment using the Content Validity Index (CVI). The instrument was considered valid if the CVI value was equal to or greater than 0.80.
Instrument reliability was assessed using Cronbach's alpha coefficient. The instrument was considered reliable when Cronbach's alpha was ≥ 0.70 [15].

Research Procedure

The study was conducted over one academic semester, following the stages of the ADDIE model. The analysis phase was conducted during Weeks 1–3 and included student needs analysis, user characteristics analysis, operating system content analysis, and analysis of existing learning media. The design phase was conducted during weeks 4–6 and involved the development of flowcharts, use case diagrams, class diagrams, learning materials, and research instruments.

The development phase was conducted during Weeks 7–10 and included the development of the Android-Based Smart Learning application, integration of learning materials, videos, and assessments, subject-matter expert validation, media expert validation, and product revision. The implementation phase was conducted during weeks 11–13 through product testing and the collection of student responses. The evaluation phase was conducted during Weeks 14–16 by analyzing the validation data, analyzing student response data, and carrying out final product revisions.

Data Analysis

The data were analyzed using descriptive quantitative statistics.

The feasibility percentage was calculated using the following formula:

Feasibility Percentage = (Obtained Score / Maximum Score) × 100%

The interpretation of feasibility percentages followed the criteria proposed by Arikunto [16], as follows:

Table 2. Feasibility Criteria

Percentage	Category
81–100%	Highly Feasible
61–80%	Feasible
41–60%	Moderately Feasible
21–40%	Less Feasible
0–20%	Not Feasible

Validity analysis was performed using the Content Validity Index (CVI), and instrument reliability was calculated using Cronbach's alpha. Student response data were analyzed using mean scores and percentages to determine the level of user acceptance of the developed learning media.

Scope and Limitations of the Study

This study focused on the development of Android-Based Smart Learning media for the Operating Systems course within the Informatics and Computer Engineering Education Program. The developed content covered an introduction to Operating Systems, Operating System Structures, Process Management, Threads, Processes and Synchronization, CPU Scheduling and Performance Evaluation, Deadlocks, Main Memory Management, Mass Storage Management, File Systems and I/O Processing, Security and Protection, Virtual Memory, and Distributed Systems.

The limitations of this study include the fact that the application can only be used on Android-based devices. In addition, the testing was conducted within a single study program, which limited the generalizability of the findings. This study also focused on feasibility and user responses and did not evaluate the effectiveness of the media in improving learning outcomes using an experimental design.

RESULTS AND DISCUSSION

Results

Analysis Phase Results

The analysis phase was conducted to identify the learning needs of the Operating Systems course. The results of observations and interviews with course instructors revealed that the learning process was still dominated by traditional lecture methods and conventional presentation media. Although learning materials were available in the form of modules and presentation slides, students continued to experience difficulties in understanding abstract concepts, such as process management, CPU scheduling, memory management, process synchronization, and virtual memory.

The student needs analysis indicated that most students used Android smartphones as their primary devices to access learning resources. Students also expressed the need for learning media that could be accessed flexibly outside classroom hours and that were equipped with instructional videos, practice exercises, and self-assessment features.

Based on these findings, an Android-Based Smart Learning application was developed to integrate learning materials, instructional videos, practice exercises, automated assessments, and immediate feedback into a single Android-based platform.

Design Phase Results

During the design phase, an application flowchart, use case diagram, class diagram, user interface design, and learning materials were developed.

The Android-Based Smart Learning application was designed with six main menus:

1. Course Outline (SAP)
2. Semester Learning Plan (RPS)
3. Learning Materials
4. Learning Videos
5. Practice Exercises
6. About

Each menu was designed according to user-friendly principles to ensure ease of use. The interface employs a consistent color scheme and simple layout to enhance user comfort during the learning process.

Development Phase Results

The development phase resulted in an Android-Based Smart Learning application that can be operated on Android devices. The application contains operating system learning materials organized according to the Semester Learning Plan (RPS).

The learning materials included an introduction to operating systems, operating system structures, process management, threads, processes and synchronization, CPU scheduling and performance evaluation, and deadlocks. In addition, the course covered main memory management, mass storage management, file systems and I/O processing, security and protection, virtual memory, and distributed systems.

In addition to learning materials, the application includes instructional videos, interactive quizzes, and automated assessments that provide immediate feedback after students complete the learning activities.

Learning Media Development Results

Splash Screen Display

Figure 5. Splash Screen Display

The splash screen serves as the initial interface displayed when users access the operating system learning application. This page presents the application identity and functions as an introductory screen before the users enter the main menu.

Main Menu Display

Figure 6. Main Menu Display

The main menu provides access to all available features, including SAP, RPS, learning materials, learning videos, practice exercises, and about.

SAP Menu Display

Figure 7. SAP Menu Display

The SAP page presents the Course Outline used as a guideline for implementing course instruction.

RPS Menu Display

Figure 8. RPS Menu Display

The RPS page presents the Semester Learning Plan, including the learning outcomes, learning materials, instructional methods, and assessment criteria.

Learning Materials Menu Display

Figure 9. Learning Materials Menu Display

The Learning Materials menu contains instructional content organized according to the learning outcomes and course topics. This feature supports independent learning through structured and comprehensible content presentations.

Learning Video Menu Display

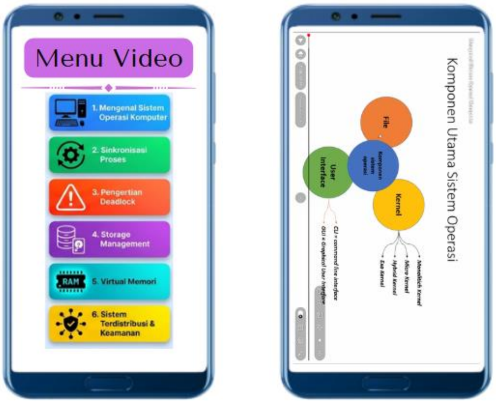

Figure 10. Learning Video Menu Display

The Learning Video menu provides instructional videos that support students' understanding of operating system concepts. This feature facilitates visual and audio learning experiences, making learning more engaging and interactive.

Practice Exercises Menu Display

Figure 11. Practice Exercises Menu Display

The Practice Exercises menu contains assessment questions that allow students to evaluate their understanding of the learning material. Upon completion, students received immediate feedback on their performance.

About Menu Display

Figure 12. About Menu Display

The About menu provides information regarding the developed learning media, including the objectives of development, a brief description of the application, and developer information..

Instrument Validity and Reliability Testing

Instrument validity and reliability testing involves evaluating an assessment tool to ensure that it accurately measures the intended variables (validity) while producing consistent and dependable results across repeated applications (reliability).

Table 3. Instrument Validity and Reliability Results

Instrument	CVI	Category	Cronbach's Alpha	Category
Subject-Matter Expert Questionnaire	0.92	Valid	0.89	Reliable
Media Expert Questionnaire	0.90	Valid	0.87	Reliable
Student Response Questionnaire	0.94	Valid	0.91	Reliable

The content validity test results indicated that all instruments achieved Content Validity Index (CVI) values exceeding 0.80, ranging from 0.90–0.94, indicating that all instruments were valid. Furthermore, reliability testing using Cronbach’s alpha produced values ranging from 0.87 to 0.91, exceeding the minimum threshold of 0.70. Therefore, all research instruments demonstrated high reliability and were suitable for collecting data.

Subject-Matter Expert Validation

The learning media were evaluated by two subject-matter experts specializing in Operating Systems.

Table 4. Subject-Matter Expert Validation Results

Assessment Aspect	Validator 1 (%)	Validator 2 (%)	Average (%)
Content Relevance	90	92	91.00
Concept Accuracy	88	90	89.00
Content Completeness	86	88	87.00
Assessment Appropriateness	89	91	90.00
Language and Presentation	87	89	88.00
Overall Average	**88.00**	**90.00**	**89.00**

The validation results demonstrated an overall average score of 89.00%. Validator 1 assigned an average score of 88.00%, whereas Validator 2 assigned 90.00%. The highest-rated aspect was Content Relevance (91.00%), whereas Content Completeness had the lowest average score

(87.00%). Overall, the developed learning media were classified as Highly Feasible, indicating that they could be utilized in learning activities with minor revisions based on expert recommendations.

Media Expert Validation

Media validation was conducted by two educational-media experts.

Table 5. Media Expert Validation Results

Assessment Aspect	Validator 1 (%)	Validator 2 (%)	Average (%)
Interface Design	90	92	91.00
Navigation Usability	87	89	88.00
Media Interactivity	89	91	90.00
Visual Consistency	88	90	89.00
Software Engineering	91	93	92.00
Overall Average	**89.00**	**91.00**	**90.00**

The media expert validation yielded an overall average score of 90.00%. Validator 1 provided an average score of 89.00%, whereas Validator 2 provided 91.00%. The highest-rated aspect was Software Engineering (92.00%), indicating that the application adhered to sound software development principles. Navigation Usability obtained the lowest average score (88.00%) but remained within the Highly Feasible category. Overall, the validation results confirmed that the developed learning media met quality standards in terms of visual design, interactivity, usability, and technical performance. Therefore, the application was categorized as Highly Feasible and suitable for implementation after refinement based on expert feedback.

Implementation Phase Results

The implementation phase involved students from the Informatics and Computer Engineering Education Program who were enrolled in the Operating Systems course. Students were provided opportunities to use the application during learning activities and subsequently completed a user response questionnaire.

Table 6. Student Response Results

Assessment Aspect	Maximum Score	Obtained Score	Percentage (%)
Ease of Use	150	137	91.33
Media Attractiveness	150	135	90.00
Content Clarity	150	132	88.00
Learning Motivation	150	138	92.00
User Satisfaction	150	135	90.00
Total	**750**	**677**	**90.27**

Note: The maximum score was calculated using a five-point Likert scale with 30 respondents (30 × 5 = 150 for each dimension).

Based on the responses of 30 students, the learning media achieved a total score of 677 out of a maximum score of 750, resulting in an average percentage of 90.27%. Learning Motivation received the highest score (92.00%), indicating that the application effectively enhanced students' enthusiasm and engagement in learning. Content Clarity obtained the lowest score (88.00%), although it remained within the very good category.

Overall, the student responses indicated that the developed learning media provided a high level of usability, an attractive design, understandable content, and user satisfaction. Therefore, with an average percentage of 90.27%, the operating system learning media was categorized as very good and considered suitable as a supplementary learning resource.

Evaluation Phase Results

The evaluation was conducted based on feedback provided by the validators and users. The improvements implemented included the following:

1. Addition of operating system installation tutorial videos.
2. Enhancement of menu navigation.
3. Addition of automated feedback features to quizzes.
4. Optimization of the user interface for various Android screen sizes.

Following these revisions, the application was deemed suitable for use in operating system learning.

Discussion

The findings of this study indicate that the developed Android-Based Smart Learning media successfully met the established feasibility standards in terms of both content and media quality. The high scores obtained from subject-matter expert validation demonstrate that the instructional materials are aligned with the learning outcomes of the Operating Systems course and possess a high level of accuracy and relevance. Furthermore, media expert validation results revealed that the application achieved excellent standards in visual design, navigation, usability, and interactivity, suggesting that the application of effective digital learning design principles can produce learning media that are both user-friendly and pedagogically appropriate for higher education students.

In addition, the highly positive responses from students indicate that the learning media contributed significantly to increasing their learning motivation and engagement throughout the learning process. The integration of instructional videos, interactive exercises, and automated assessments provided students with a more engaging and dynamic learning experience than conventional lecture-based instruction, which primarily relies on presentation slides. The availability of learning resources through mobile devices also enables students to access learning materials anytime and anywhere, thereby supporting independent and flexible learning practices.

These findings are consistent with the Multimedia Learning Theory, which argues that combining multiple forms of media, including text, images, audio, and video, can improve conceptual understanding by engaging multiple cognitive channels simultaneously during learning. The multimedia elements embedded within the application facilitated the presentation of complex operating system concepts in a more comprehensible and visually appealing manner. Moreover, the results support the Smart Learning concept, which emphasizes flexibility, personalization, accessibility, and interactivity within digital learning environments. Through mobile technology, students can learn at their own pace while actively interacting with the learning content, thus creating a more learner-centered educational experience.

Overall, the results suggest that Android-Based Smart Learning media can serve as an effective supplementary learning resource for Operating Systems courses and may contribute to improving the quality of learning in higher education. The successful integration of mobile learning technology with multimedia and smart learning principles demonstrates the potential of digital learning innovations to address the challenges associated with teaching complex and abstract computing concepts.

CONCLUSION

This study aimed to develop Android-Based Smart Learning media for the Operating Systems course as a solution to learning challenges that are still predominantly characterized by traditional lecture-based instruction and conventional presentation media. Based on the needs analysis, students required learning media that are flexible, interactive, and accessible anytime through mobile devices to facilitate the understanding of abstract and complex operating system concepts. Therefore, this study developed Android-based learning media using the ADDIE model, which consists of the Analysis, Design, Development, Implementation, and Evaluation phases.

The findings demonstrate that the Android-Based Smart Learning media were successfully developed in accordance with the learning needs of the Operating Systems course. The resulting application incorporates various instructional features, including digital learning materials, instructional videos, interactive exercises, automated assessments, and immediate feedback, all of which are accessible through Android devices only. Validation results from subject-matter and media experts indicated that the developed media were highly feasible, while student responses were very positive. These findings suggest that Android-Based Smart Learning media possess high quality in terms of content, visual design, interactivity, usability, and educational value in supporting the learning process.

Accordingly, the research objectives formulated in the introduction were achieved. The development of Android-Based Smart Learning media has proven to provide an alternative learning resource that aligns with the characteristics of students in the digital era, supports self-directed learning, enhances learning motivation, and facilitates a more effective understanding of operating system concepts. Furthermore, the findings reinforce previous studies, indicating that integrating mobile technology and smart learning approaches can improve the quality of students' learning experiences.

In addition to contributing to the development of digital learning media for the Operating Systems course, this study also provides opportunities for further research. Future research may expand the application to a multi-platform environment that supports Android, iOS, and web-based systems. Further development may incorporate interactive simulation features, real-time visualization of operating system processes, gamification elements, artificial intelligence (AI) technologies, and integration with Learning Management Systems (LMS). Moreover, future studies could investigate the effectiveness of the developed media in improving learning outcomes, critical thinking skills, problem-solving abilities, and students' digital literacy through broader experimental research designs.

Overall, this study demonstrates that the development of Android-Based Smart Learning media represents a relevant educational innovation for supporting the digital transformation of higher education. The developed media function not only as a means of delivering instructional content but also as an interactive, adaptive, and student-centered learning environment, thereby offering significant potential to continuously enhance the quality of operating system education.

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AUTHOR CONTRIBUTION STATEMENT

KPW contributed to the conceptualization of the study, research design, development of the Android-Based Smart Learning media, and supervision of the manuscript preparation. H contributed to the ADDIE-based methodological organization, development process, expert validation coordination and data analysis. AH contributed to the student response data collection, interpretation of findings, discussion refinement, manuscript editing, and final approval of the manuscript. All the authors have reviewed and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used ChatGPT by OpenAI during the preparation of this manuscript for language refinement, grammar checking, sentence restructuring and improvement of academic clarity. The tool was not used to generate research data, conduct analyses, or replace the authors' scholarly interpretation. After using the tool, the authors thoroughly reviewed, verified, and edited the manuscript. The authors take full responsibility for the accuracy, originality, interpretation, and final content of this publication.

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