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The ADDIE and Waterfall models as a framework for developing learning media (a case study: circulatory system learning media)

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Abstract—The ADDIE model, while effective for instructional design, often lacks a structured approach to the technical aspects of software development. This study introduces a combined ADDIE-Waterfall framework to create learning media that are both pedagogically effective and technically sound. Using a Research and Development (R&D) method, a learning application for the high school biology topic of the circulatory system was created. The product was evaluated for feasibility through expert validation, practicality through user response questionnaires (n=150), and effectiveness using pre-test and post-test scores to calculate a normalized gain (N-Gain) score. The results demonstrated high quality, with an expert validation score of 92% (“Very Feasible”) and a user response score of 95% (“Very Good”). The learning media were also effective, showing a significant improvement in student learning outcomes with an N-Gain score of 0.63, indicating moderate effectiveness. The findings confirm that integrating the ADDIE and Waterfall models provides a comprehensive framework for developing high-quality, effective educational software. This combined approach successfully addresses both instructional and technical requirements, resulting in a product that is well-received by users and improves learning.

Keywords—*addie; learning effectiveness; learning media; research and development; waterfall.*

1. Introduction

In instructional development and the creation of learning media, the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model has long been a primary framework (Andi Rustandi & Rismayanti, 2021). This model is structured to offer systematic and iterative guidance in producing high-quality learning products (Branch, 2009). Each stage in the ADDIE model has a specific function, from needs analysis, media design, and material development to implementation and the evaluation of outcomes. The main advantage of ADDIE is its flexibility and its focus on instructional quality and continuous evaluation, which allows for iterative improvements to the learning product.

However, while the ADDIE model is highly effective in its instructional aspects, it places less emphasis on software engineering, particularly concerning the comprehensive and detailed system development processes required for creating digital application-based learning media.

In the context of software development, the Waterfall model is a classic method known for its linear and sequential approach, which consists of requirement analysis, system design, implementation, testing, and maintenance stages (Kayande & Phadnis, 2024; Pressman & Maxim, 2020). The Waterfall model requires each stage to be fully completed before moving to the next, which facilitates the identification and correction of errors early in the process, reducing the risk of critical failures in the

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final stages. A six-stage Waterfall model was combined with the five-stage ADDIE model, adapted to the function of each stage in the learning media development process (Wan Ali & Wan Yahaya, 2023).

The ADDIE model, which does not thoroughly accommodate technical aspects, could potentially lead to the development of learning media that are suboptimal from a software quality standpoint, for example, due to a lack of system validation, bugs, or incompatibility with technical user needs. Therefore, integrating stages from the Waterfall model into the ADDIE model can address this shortcoming.

ADDIE provides a flexible framework for designing and evaluating learning effectiveness. Meanwhile, the Waterfall model emphasizes a structured, systematic, and phased workflow, thereby minimizing errors during the technical development process. By combining the two, the design process can be more directed yet adaptive: Waterfall ensures order in the technical stages, while ADDIE maintains that the resulting product remains relevant, effective, and aligned with user needs. This combination not only improves the quality of the final product but also enhances efficiency in terms of time, cost, and sustainability in implementation.

This integration is not merely a fusion of two models but the creation of a holistic development framework where pedagogical and technical aspects form a unified, complementary whole. Consequently, the learning media not only meet learning needs effectively and efficiently but are also technically sound in terms of software quality, security, and performance (Sommerville, 2016). This approach can also improve coordination within the learning media development team, which typically includes instructors, learning designers, and software engineers, thus minimizing miscommunication and increasing productivity.

In practical terms, this ADDIE model, augmented with the Waterfall process, allows for software verification and validation at each development stage, ensuring that the technical specifications of the learning media are met before proceeding to the next stage (Saravanas & Curinga, 2023). This is crucial for producing learning media that is reliable, user-friendly, and responsive to the evolving learning needs of the digital era.

Although modern methods such as Agile are now more widely used for their flexibility in handling dynamic requirement changes, the choice of Waterfall in this study has strong contextual reasons. First, the requirements for learning media development are relatively stable from the initial stage, making Waterfall's linear approach more efficient than Agile, which accommodates frequent changes (Pressman & Maxim, 2020). Second, the ADDIE model already provides an iterative mechanism for pedagogical aspects, so using Agile could be redundant, whereas Waterfall offers a clearer technical structure to support documentation, validation, and software quality control (Sommerville, 2016). Third, in Research and Development (R&D) based studies, Waterfall is more suitable because the development stages can be documented in detail, facilitating academic evaluation and research replication (Kayande & Phadnis, 2024). Therefore, the selection of Waterfall is not simply a retention of a classic method but a deliberate choice to ensure a balance between the pedagogical flexibility of ADDIE and the systematic technical structure of Waterfall.

This study employs an R&D approach, a research method

that aims to produce a specific product while testing its effectiveness (Gall et al., 2003). The product developed is a technology-based learning medium using a modified ADDIE development model that incorporates technical stages from the Waterfall model.

The development of learning media with this ADDIE-Waterfall framework was applied to the topic of the circulatory system, a biology subject for eleventh-grade high school students.

2. Method

2.1. Development stages

The stages for developing the learning media with the modified ADDIE-Waterfall model are illustrated in Fig. 1.

a. Analysis (A)

The analysis stage aims to analyze learning needs and technical specifications. Activities include:

1. Learning needs analysis: Identifying learning objectives, learner characteristics, and the learning context.
2. Technical analysis (Waterfall: Requirement Analysis): Formulating functional and non-functional specifications for the learning media, hardware and software requirements, and system constraints.

b. Design (D)

The design stage is conducted to visualize the concept of the learning media. Activities include:

1. Instructional design: Structuring the material flow, learning strategies, and storyboards.
2. System design (Waterfall: System Design): Creating the system architecture, designing the user interface (UI/UX), and the database.

c. Development (D)

This stage includes the process of creating and integrating learning content and application programming. Activities include:

1. Developing media and learning content according to the instructional design.
2. Technical implementation (Waterfall: Implementation): Writing program code, integrating features, and applying the interface design.
3. Internal testing (Waterfall: Testing): Performing unit tests, integration tests, and bug fixes before implementation for users.

d. Implementation (I)

This stage involves the application of the learning media in a real environment. Activities include:

1. Distributing and installing the learning media for a small group of users (Waterfall: Deployment/Installation).
2. Conducting a limited trial to obtain initial feedback on instructional and technical performance.

e. Evaluation (E)

Evaluation is performed both formatively and summatively. Activities include:

1. Formative evaluation at each development stage for iterative improvement.
2. Summative evaluation to assess the effectiveness of the learning media in achieving learning objectives and

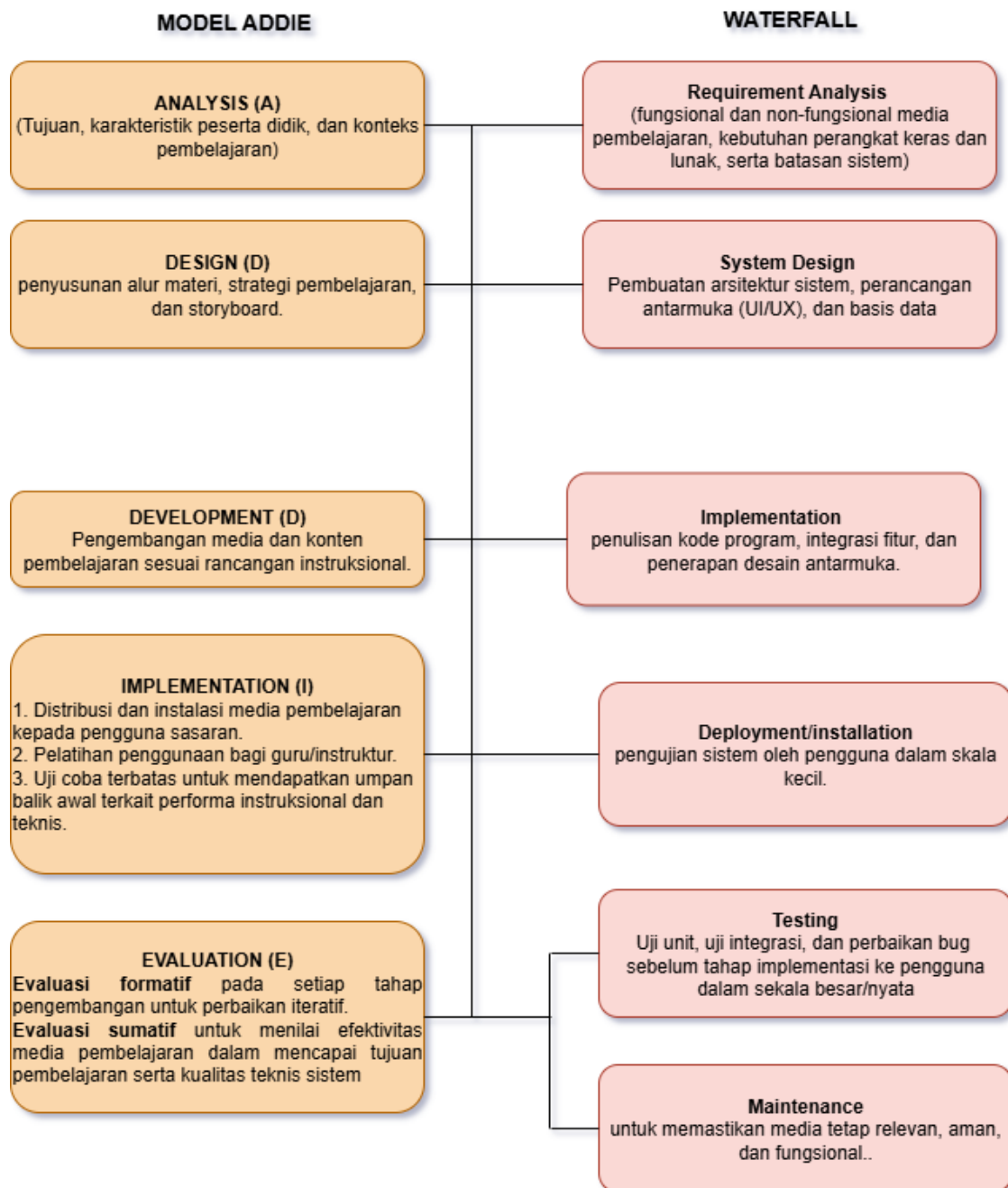


Fig. 1. Design of the integration of the ADDIE and Waterfall models

the technical quality of the system.

- Maintenance and updates (Waterfall: Testing and Maintenance) to ensure the media remains relevant, secure, and functional.

2.2. Research instruments

Research instruments were used to collect data regarding the feasibility, practicality, and effectiveness of the learning media developed with the ADDIE + Waterfall model. The instruments included expert validation sheets, user response

questionnaires, and learning outcome tests.

1. Expert validation

The expert validation stage involved assessing the media's feasibility from the perspectives of material and learning design by a biology teacher, and from a technical software perspective by a computer science academic from Mulawarman University. The assessment used a Likert scale of 1-5 as follows: 1 = not feasible, 2 = less feasible, 3 = fairly feasible, 4 = feasible, 5 = very feasible (Habibi & Agustini, 2022; Riduwan, 2023). The calculation of

Table 1. Interpretation of expert validation

Percentage	Criteria
81% – 100%	Very Feasible
61% – 80%	Feasible
41% – 60%	Fairly Feasible
21% – 40%	Less Feasible
0% – 20%	Not Feasible

Table 2. Interpretation of user response

Percentage	Criteria
76% – 100%	Very Good
56% – 75%	Good
40% – 55%	Fair
< 40%	Poor

Table 3. Interpretation of the normalized gain score

Value	Criteria
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Moderate
$g < 0.3$	Low

feasibility is using (1), with interpretation criteria that can be seen in Table 1.

$$\text{feasibility (\%)} = \frac{\sum \text{obtained score}}{\sum \text{maximum score}} \times 100\% \quad (1)$$

2. User validation

User responses were collected from 150 students and the biology teacher to assess the practicality and user experience of the learning media. The calculation is using (2), with the response interpretation shown in Table 2.

$$\text{response (\%)} = \frac{\sum \text{obtained score}}{\sum \text{maximum score}} \times 100\% \quad (2)$$

3. Media effectiveness

This stage tested the effectiveness of the learning media in improving student understanding through the following steps.

- (1) Measuring individual and class average scores calculated using (3).

$$\text{student score (\%)} = \frac{\text{obtained score}}{\text{maximum score}} \times 100\% \quad (3)$$

With the class average score that can be calculated using (4).

$$\bar{x} = \frac{\sum X}{N} \quad (4)$$

where

$\bar{x}$ = average score

$\sum X$ = sum of student scores

N = number of students in the class.

(2) Normalized gain test

This test is used to measure the increase in understanding or effectiveness of learning after a treatment is administered. This formula calculates the difference between the post-test and pre-test scores, then normalizes it by the ideal score, as illustrated in (5) (Navarrete et al., 2024). The interpretation of the normalized gain value can be seen in Table 3.

$$g = \frac{\text{post}_{\text{test}} - \text{pre}_{\text{test}}}{X_{\text{max}} - \text{pre}_{\text{test}}} \quad (5)$$

where

g = normalized gain

$\text{post}_{\text{test}}$ = post-test score

pre_{test} = pre-test score

X_{max} = maximum score

3. Results

This research produced a reference framework for ADDIE-Waterfall in the development of learning media and its product, which can be seen in Fig. 2.

a. Expert validation

The expert validation instrument was applied to three aspects: material, learning design, and technical software. Each aspect was rated by an expert on a Likert scale of 1–5. The results showed an average score of 92%, placing it in the "Very Feasible" category according to the interpretation table.

b. User response

User responses (from 150 students, a biology teacher, and a computer science academic from Mulawarman University) to the learning media were obtained through a questionnaire assessing ease of use, appearance, interaction, and satisfaction. The resulting percentage was 95%, which falls into the "Very Good" category.

c. Media effectiveness (learning outcome test and normalized gain)

The effectiveness was calculated using the following data:

1. The average student pre-test score was 62.
2. The average student post-test score was 86.
3. The ideal maximum score was 100.

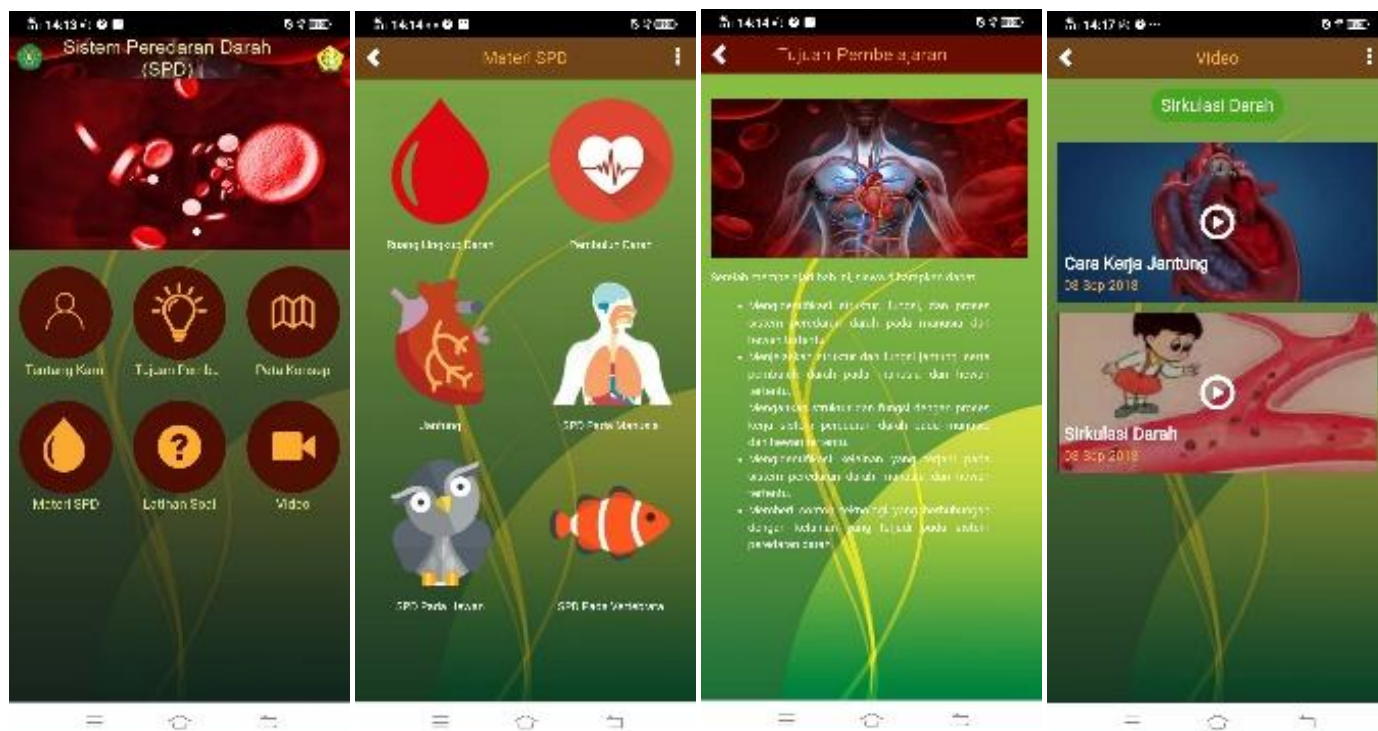


Fig. 2. The learning media product

The increase, calculated using the normalized gain formula, yielded a value of $g = 0.63$, which is in the "Moderate" category, as shown in calculation (6).

$$\begin{aligned}
 g &= \frac{\text{post}_{\text{test}} - \text{pre}_{\text{test}}}{X_{\text{max}} - \text{pre}_{\text{test}}} \\
 &= \frac{86 - 62}{100 - 62} \\
 &= \frac{24}{38} = 0.63
 \end{aligned}
 \quad (6)$$

With 150 students, the average class score also reached 86, thus showing that the learning media was effective in improving students' understanding.

4. Discussion

4.1. Media feasibility

Media feasibility was measured to determine the quality of the media, assessed by a biology teacher and a computer science academic from Mulawarman University. The expert validation results indicate that the learning media developed with the integrated ADDIE and Waterfall models are in the very feasible category (92%). This demonstrates that the developed media meets the standards for content, instructional design, and technical software aspects.

4.2. User response

The user response was intended to ascertain the actual

utility of the developed learning media. The responses from teachers and students showed a score of 95% (very good). This means the learning media was considered easy to use, interactive, and suitable for learning needs. Support from the teacher also confirmed that the media is practical for classroom implementation.

4.3. Media effectiveness

The effectiveness of the learning media was aimed at determining the impact of its development on the circulatory system topic, based on learning test results. The test results showed significant improvement from the pre-test to the post-test. A normalized gain score of 0.63 indicates that the media's effectiveness is in the moderate-to-high category. Thus, this media successfully improved high school students' understanding of circulatory system concepts.

4.4. Implications

The development of learning media with a combined model strongly supports software development in the educational field. Creating media with the integration of ADDIE and Waterfall can meet both pedagogical and technical requirements. The media is not only feasible for use in learning but also has a tangible impact on improving student learning outcomes.

5. Conclusion

The development of learning media based on the ADDIE–Waterfall framework has been proven to be highly feasible for use in education. Expert validation yielded a score of 92%, categorized as very feasible, while the user response from 150

students and a biology teacher reached 95%, categorized as very good. These results show that the media not only meet the feasibility standards for material, design, and technical aspects but are also very well-received by users for being easy to use, interactive, and aligned with learning needs.

In terms of effectiveness, this media was able to improve student learning achievements. The class average score increased significantly from 62 (pre-test) to 86 (post-test), with an N-Gain score of 0.63, which falls into the moderate-to-high category. This proves that integrating the ADDIE model with the Waterfall approach can produce holistic learning media that is strong from a pedagogical standpoint and has assured technical quality. This media has the potential for broader development across various other subjects in the digital era.

Data availability

All data produced or examined during this study are presented in this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' contributions

All authors participated in the study design, writing, and manuscript revision. AR drafted the initial manuscript, D revised it. All authors have reviewed and approved the final manuscript.

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