Developing Interactive Illustrated Digital Modules to Improve Biology Learning Outcomes

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Abstract. Biology learning in the 21st century requires the integration of technology to address the limitations of conventional instructional media in visualizing complex biological systems. This research and development (R&D) study employed the 4-D model (Define, Design, Develop, and Disseminate) to develop and evaluate an Interactive Illustrated Module based on the Picture and Picture learning model for the human digestive system at MATQ Al-Anshor Ambon. The results of expert validation indicated that the module was highly valid, with a validity score of 96.67%, and highly practical, based on student responses of 89.12%. The effectiveness evaluation showed a significant improvement in students' learning outcomes in Grade XI, with mean scores increasing from 42.50 (pre-test) to 84.47 (post-test). The calculated normalized gain (N-gain) score of 0.75 indicates a high level of effectiveness. The findings suggest that the developed module is a valid, practical, and effective instructional medium for enhancing students' understanding of abstract biological concepts.

Keywords: Interactive, Illustrated Module, Digital visual media, Learning outcomes.

1 Introduction

Modern biology education continues to evolve in response to 21st-century learning demands, where the integration of educational technology has become essential for enhancing instructional effectiveness [1]. In the digital era, teachers are expected to innovate by developing instructional media that facilitate students' understanding of complex and abstract concepts [2]. In biology education, particularly in topics related to the human digestive system, one of the main challenges is students' difficulty in visualizing biochemical processes that cannot be directly observed. Conventional printed textbooks are often insufficient to address this limitation due to their static presentation format [3].

To overcome these limitations, the use of interactive multimedia is widely recognized as an effective instructional approach. Research indicates that visual-based digital learning materials can enhance information retention by engaging both visual and verbal cognitive channels, thereby supporting more effective cognitive processing [4]. Digital learning tools that integrate multimedia elements such as images, audio, video, and animations enable the transformation of static materials into interactive learning resources. These resources enhance learner engagement

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and support flexible, self-paced learning, allowing students to learn according to their individual needs [5].

Therefore, there is a need for the development of innovative instructional media that integrate visual representation and interactive learning design to support students' understanding of abstract biological concepts. In response to this need, this study develops an Interactive Illustrated Module based on the Picture and Picture (P&P) learning model. The module is designed by integrating sequential visual representation with interactive digital flipbook technology to support structured concept visualization and student centered learning.

To address this gap, this study develops an Interactive Illustrated Digital Module by integrating the Picture and Picture (P&P) learning model with an interactive flipbook-based learning system. This integration forms a structured visual sequencing approach supported by multimedia interaction, which has rarely been implemented in biology instruction at the secondary education level. The module is designed to improve students' conceptual understanding and learning outcomes in the human digestive system topic at MATQ Al-Anshor Ambon.

2 Review of related literature

2.1 Learning outcomes in biology

Learning outcomes in biology education are key indicators of educational success, reflecting the extent to which students achieve the intended instructional objectives in a learning process [6]. In biology education, these outcomes encompass cognitive, psychomotor, and affective domains, which together represent students' comprehensive learning achievements. Mastery of learning outcomes is particularly important in understanding hierarchical and complex biological topics, such as organ systems.

Low learning outcomes in biology are often associated with students' difficulties in understanding abstract scientific concepts, especially those involving biochemical and microscopic processes [7]. To address these challenges, the development of an authentic and supportive learning environment is required. In this context, instructional media serve as a cognitive bridge that helps students connect abstract biological concepts with more concrete representations, thereby facilitating conceptual understanding [8]. Previous studies in biology education have shown that visual-based instructional approaches not only improve conceptual understanding but also enhance learning outcomes through better knowledge retention and academic achievement.

2.2 Picture and picture (p&p) learning model

The Picture and Picture (P&P) learning model is a cooperative instructional approach that uses sequential visual representations as the main learning stimulus. In this model, students are guided to arrange and interpret a series of images into a logical sequence in order to construct conceptual understanding [9]. This process requires active cognitive engagement, as learners must analyze relationships between visual elements rather than receiving information passively. In biology learning, particularly in topics involving processes and systems such as the human digestive system, the structured sequencing of images helps students visualize step-by-step biological mechanisms that are otherwise difficult to observe directly. Empirical studies have shown that structured visual interpretation can improve comprehension and retention by

strengthening mental representation of scientific concepts [10]. In addition, collaborative discussion during image arrangement activities encourages students to articulate reasoning and refine conceptual understanding through peer interaction, thereby supporting deeper learning outcomes [11].

2.3 Innovation in digital teaching materials

Digital transformation in education has shifted instructional design from static content delivery toward more interactive and learner-centered approaches. Modern digital learning environments integrate multiple modalities such as images, narration, animation, and video to present information in ways that align with human cognitive processing capacity. According to the Cognitive Theory of Multimedia Learning (CTML), learning becomes more effective when verbal and visual information are processed in an integrated manner within working memory, provided that instructional design minimizes cognitive overload and supports meaningful processing [12]. In this regard, digital learning resources are not merely presentation tools, but structured environments that facilitate active meaning-making.

In biology education, digital visualization is particularly important because many biological processes occur at microscopic or abstract levels that cannot be directly observed. Interactive visual representations help learners translate abstract physiological and biochemical processes into more concrete mental models. This is especially relevant for topics such as the human digestive system, where understanding depends on the ability to visualize sequential and interrelated processes [13].

2.4 The role of technology and digital applications

The use of educational technology supports curriculum implementation by enabling the design of learning environments that are more interactive, structured, and aligned with student-centered learning principles. In practice, technology facilitates the development of instructional materials that support active learning through collaboration, visualization, and multimodal presentation [14,15]. In biology instruction, digital authoring tools such as Flip PDF Professional enable educators to transform static materials into interactive flipbooks that present content in a structured and visually rich format. This transformation is particularly relevant for abstract biological topics, as it allows step-by-step visualization of concepts while integrating multimedia elements such as images, audio explanations, and video demonstrations [16]. Furthermore, digital modules improve instructional flexibility by allowing learners to access materials anytime and enabling teachers to revise content efficiently based on learning needs. Compared to printed materials, digital resources are more adaptive to updates in curriculum and more suitable for supporting continuous learning in modern educational environments [17].

2.5 Contextual analysis for biology materials

Effective instructional development requires a thorough understanding of students' needs and target competencies. Target needs refer to real-life competencies, such as understanding the functions of human physiological organs. Learning needs refer to the specific knowledge and skills required to achieve those competencies. This analysis ensures that the Interactive Illustrated Module is relevant to Grade XI Biology learning. Specifically, it addresses students' difficulties in visualizing biological processes, as identified at MATQ Al-Anshor Ambon.

3 Methods

3.1 Research Design and Development

This study employed a Research and Development (R&D) approach using the 4-D model, which consists of four systematic stages: Define, Design, Develop, and Disseminate [19]. The Interactive Illustrated Module was developed to support students in visualizing abstract biological concepts, particularly the human digestive system. The module is designed to include: (1) instructional objectives, (2) initial guidelines for student activities, (3) multimedia-based learning resources, (4) interactive discussion questions, (5) content summaries, (6) evaluation activities, and (7) answer keys.

3.2 Instruments

To ensure the quality and effectiveness of the developed module, four types of instruments were used: (1) validation sheets for media, content, and language experts to assess the validity of the module; (2) practicality questionnaires to obtain feedback from students as the primary users; (3) interview guidelines for initial data collection; and (4) learning achievement tests (pre-test and post-test) to measure the impact of the module on students' learning outcomes. All instruments were tested for validity and reliability prior to their use.

3.3. Participants

The study was conducted at MATQ Al-Anshor Ambon and involved 30 Grade XI students as the primary test group. Prior to the implementation of the Interactive Illustrated Module, a pre-test was administered to assess students' prior knowledge. Subsequently, the students engaged with the digital module designed to facilitate the exploration of the complex processes of the human digestive system through visual and interactive learning media.

3.4 Data Collection and Analysis

Data were collected through expert validation, student questionnaires, and learning achievement tests. The quantitative data were analyzed using descriptive statistics to determine the percentages of validity and practicality (V). To evaluate improvements in learning outcomes, the normalized gain (N-gain) score (g) was calculated based on the comparison between pre-test and post-test results. This analysis was conducted to determine whether the developed module met the established criteria for effectiveness within the research framework.

4 Results and Discussion

4.1. Validation and Practicality Results .

The development process began with expert validation covering content, media, and language aspects. These evaluations were conducted to ensure the feasibility of the module for classroom implementation. The average expert validation score was 96.67%, which was categorized as very valid. Furthermore, students' responses regarding practicality reached 89.12%, indicating that the module was highly practical. The detailed results of the expert validation are presented in Table 1.

Table 1. Validation results from expert reviewers.

No.	Assessment Aspect	Score (%)	Category
1	Content Aspect	98.00	Very Valid
2	Media Aspect	95.00	Very Valid
3	Language Aspect	97.00	Very Valid
Average Total Score		**96.67**	**Very Valid**

Student Learning Outcomes (Effectiveness)

Data obtained from 30 students indicated a significant improvement between pre-test and post-test scores. These results were used to measure the effectiveness of the Interactive Illustrated Module in the learning process. The statistical summary is presented in Table 2.

Table 2. Statistical analysis of student learning outcomes

Variable	Mean Score	Standard Deviation	Min Score	Max Score
Pre-test	42.50	5.24	35	55
Post-test	84.47	4.80	75	95

The effectiveness of the Interactive Illustrated Module was further analyzed using the normalized gain (N-gain) formula. The calculated N-gain score was 0.75, indicating a high level of effectiveness in improving students' learning outcomes.

4.2 Discussion

The findings indicate that the Interactive Illustrated Module improves students' learning outcomes in biology, particularly on the human digestive system. This improvement is closely related to the structured visual sequencing embedded in the Picture and Picture (P&P) learning model. By organizing biological processes into ordered visual representations, students are supported in constructing step-by-step conceptual understanding, which reduces difficulty in interpreting abstract physiological mechanisms.

The use of sequential images also promotes active cognitive engagement, as students are required to interpret relationships between visual elements rather than receiving information passively. This encourages students to actively relate visual information in sequence, helping them understand how biological processes are connected step by step.

The combination of text, images, and interactive elements reduces cognitive load and supports meaningful learning, particularly for complex biological topics that involve multistep processes, consistent with the Cognitive Theory of Multimedia Learning (CTML), which emphasizes that learning is enhanced when verbal and visual information are processed in an integrated manner. The combination of text, images, and interactive elements in the digital module helps reduce cognitive overload and supports meaningful learning, especially for complex biological topics that involve multistep processes.

In addition, the digital flipbook format contributes to learning accessibility and learner autonomy. Students can navigate materials independently, revisit specific sections, and interact with multimedia content at their own pace. This supports self-regulated learning, which is essential in modern biology education.

The quantitative results further support these findings. The decrease in standard deviation from 5.24 to 4.80 indicates more consistent learning achievement among students after the intervention. Moreover, the N-gain score of 0.75 confirms a high level of learning effectiveness,

suggesting that the integration of structured visual learning and digital interactivity positively contributes to both achievement and learning consistency.

5. Conclusion

The findings of this study indicate that the Interactive Illustrated Module is suitable and effective for use in biology learning, particularly on the topic of the human digestive system. The module demonstrated a very high level of validity (96.67%) and practicality (89.12%), indicating its appropriateness for classroom implementation. In addition, the improvement in students' learning outcomes, as shown by an N-gain score of 0.75, reflects a high level of effectiveness in supporting learning achievement. These results suggest that the integration of interactive visual media can support students in understanding abstract biological concepts and may contribute to improved learning engagement in digital-based learning environments.

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