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Articulate Storyline Interactive Media for Grade XI Digestive-Excretory Learning via ASSURE

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Abstract

Students' low understanding of complex human digestive and excretory system materials shows a gap in the use of technology-based interactive learning media in high school/MA. This study aims to develop and evaluate the validity, practicality, and effectiveness of Articulate Storyline-based interactive media for learning the human digestive and excretory system in grade XI using the ASSURE design model. The research innovation lies in the integration of interactive multimedia technology with the ASSURE systematic learning approach which includes student analysis, goal setting, media-method selection, material utilization, and evaluation-revision. The research and development (R&D) method was applied with the subjects of grade XI high school/MA students. Data was collected through pretests, user response questionnaires, and expert validation. The results showed that the developed media achieved very high validity (> score of 0.80), excellent practicality of teacher and student assessments (81-100%), and significant effectiveness with an average N-Gain of 0.7227 indicating a substantial improvement in learning outcomes. These findings indicate that the Articulate Storyline interactive media with the ASSURE design is effective in improving understanding of complex biology concepts, making a significant contribution to technology-based science learning innovations in Indonesia, and has the potential to be widely applied for a more engaging and effective transformation of biology education.

Keywords: Interactive Media; Articulate Storyline; ASSURE; Digestive System; Excretory System

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INTRODUCTION

The digital technology revolution has changed the learning paradigm in global educational institutions, demanding the adaptation of the education system to the needs of the digital era. The concept of Society 5.0 developed by Japan emphasizes the integration of digital technology in all aspects of life, including education, where technology is not only a tool but also a foundation in the learning process (Szpulak et al., 2023). The Government of Indonesia through the Ministry of Education and Culture has launched the digital transformation of education as a national priority, with the implementation of the Independent Curriculum that emphasizes flexibility, relevance, and personalization of learning according to student characteristics. Data from the Central Statistics Agency shows that the digital literacy level of Indonesian students is still at the level of 3.47 from a scale of 5, indicating the need to accelerate

the integration of technology in learning. This condition is a particular challenge in science learning, especially biology, which requires complex visualization to understand abstract concepts. Digital transformation in biology education is an urgent need to improve the quality of learning and prepare students for the challenges of the 21st century.

The learning of biology, particularly the material of the human digestive and excretory systems, faces significant conceptual complexity. Both of these organ systems involve physiological processes that are abstract and cannot be directly observed, thus requiring a learning strategy that can effectively visualize these processes (Sangkham et al., 2022). Conventional learning methods that rely on lectures and static media have proven to be less effective in facilitating an in-depth understanding of concepts. The preliminary study conducted at SMA Negeri 3 Takalar involved 60 grade XI students using a quantitative descriptive survey method. The results showed that 70% of students had difficulty understanding the working mechanisms of the digestive and excretory systems, 85% of students found conventional learning less interesting, and 90% of students expressed the need for interactive learning media. A survey of two biology teachers showed that the implementation of interactive technology in learning is still limited, although all teachers acknowledged the urgency of learning media innovation (Liu et al., 2021).

This phenomenon is in line with national findings that show that the majority of biology learning in Indonesia still uses a teacher-centered approach with the dominance of lecture methods and the use of conventional learning media. This condition has an impact on the low learning achievement of students and the non-fulfillment of the Learning Goal Achievement Criteria (KKTP) set out in the Independent Curriculum. Interactive multimedia has been shown to be effective in improving the quality of biology learning through the integration of various visual, audio, and animation elements that can concretize abstract concepts. Song et al. (2022) stated that interactive media is able to accelerate the understanding of complex concepts that are difficult to convey through conventional media. Research (Syuhada & Risnawaty, 2022) shows that interactive multimedia-based learning can increase students' motivation to learn and optimize learning outcomes.

Articulate Storyline is an interactive media development platform that allows the integration of text, images, animations, videos, and simulations in one interesting and interactive learning media (Munawarah et al., 2022). The platform offers advanced features that enable the development of learning content that is responsive and adaptive to the needs of students. The ASSURE development model (Analyze Learners, State Objectives, Select Methods/Media/Materials, Utilize Media and Materials, Require Learner Participation, Evaluate and Revise) was chosen as a framework to ensure the suitability of the developed media with the characteristics of the students and learning objectives. This model has proven effective in the development of student-centered technology-based learning (Prasetyo & Astuti, 2021).

Literature analysis shows that research on the development of interactive multimedia using Articulate Storyline with the ASSURE model for human digestive and excretory system materials Phase F is still very limited. Most previous studies have used ADDIE or TPACK development models with a focus on different biological materials. The novelty of this research lies in the combination of the use of Articulate

Storyline with the ASSURE model, as well as the integration of virtual laboratory features and liveworksheets that have not been widely explored in the context of learning human organ systems. Generation Z who are digital natives have different learning characteristics, where they are more responsive to digital and interactive learning media. Ansari and Khan (2020) shows that interactive media with simulation, animation, and self-navigation features can optimize students' active and reflective learning. This condition strengthens the urgency of developing learning media that is in accordance with the characteristics of the digital generation.

This research aims to develop interactive multimedia using the Articulate Storyline application with the ASSURE learning design model on the human digestive and excretory system material for Phase F class XI SMA/MA. Specifically, this study examines the validity, practicality, and effectiveness of media developed based on the criteria (Ines et al., 2024) which includes aspects of content, constructs, and practical usability. Validity indicators refer to the suitability of the content with the curriculum and academic standards, as well as the feasibility of the media construction according to expert assessment. Practicality is measured through the ease of use of media by teachers and students, as well as the efficiency of implementation in learning. Effectiveness is evaluated based on the improvement of student learning outcomes and the achievement of the set learning objectives, using the Diaz-Pinto et al. (2024) to measure the improvement of concept understanding.

This research is expected to make a theoretical contribution to the development of a technology-based learning model that integrates constructivism theory with digital technology. Practically, this research produces learning media products that can be widely implemented to improve the quality of biology learning at the intermediate level. The significance of this research lies in efforts to increase students' digital literacy and optimize science learning through technology, in line with Indonesia's vision of education in facing the digital era. This research also contributes to the development of learning innovations that support the achievement of the Sustainable Development Goals (SDGs) goals in the education sector, especially in ensuring inclusive and equitable quality education.

METHOD

Design and Research Approach

This study uses a Research and Development (R&D) approach by adopting the ASSURE development model (Albus et al., 2021). The ASSURE model was chosen because of its systematic characteristics and oriented to a learner-centered approach, in contrast to the ADDIE model which focuses more on systematic design or TPACK which emphasizes technological knowledge integration. The ASSURE model consists of six successive stages: (1) Analyze Learners; (2) State Objectives (formulation of learning objectives); (3) Select Methods, Media, and Materials; (4) Utilize Media and Materials; (5) Require Learner Participation; and (6) Evaluate and Revise. The research design used a one-group pretest-posttest design to test the effectiveness of the developed interactive media. This design was chosen because the research focus was on measuring the improvement of student understanding before and after the implementation of learning media, with students as the sole subject receiving the same treatment.

Sampling Subjects and Techniques

The research population was all grade XI students of SMA Negeri 3 Takalar who participated in biology learning in the Independent Curriculum Phase F. The research sample consisted of 34 students in grade XI Alfred Nobel who were selected using the purposive sampling technique. The sample selection criteria are operationalized based on: (1) students have learned basic concepts of biology in the previous phase; (2) have access to and basic skills in the use of digital technology and (3) have not studied the material of the human digestive system and excretion in depth. The purposive sampling technique is used because it allows researchers to select subjects that have specific characteristics according to the needs of developmental research (Gall et al., 2007). A sample size of 34 students was considered adequate for developmental research based on recommendations (Cohen et al., 2013) which suggests a minimum of 30 subjects for small-scale experimental research.

Stages of ASSURE Model Development

The development of the learning media was guided by the ASSURE model, which comprises six sequential stages. In **Stage 1: Analyze Learners**, student characteristics were examined using observations, informal interviews, and demographic questionnaires. Key aspects analyzed included students' learning styles, media preferences, digital literacy levels, and prior knowledge of human organ systems. **Stage 2: State Objectives** involved formulating learning objectives aligned with the Learning Outcomes of the Independent Curriculum Phase F, referring to the revised Bloom taxonomy and targeting cognitive levels from C1 (remembering) to C6 (creating), specifically focused on the human digestive and excretory systems.

Figure 1. ASSURE Model Flowchart

Stage 3: Select Methods, Media, and Materials identified Articulate Storyline as the development platform due to its capacity to incorporate interactive multimedia, virtual simulations, and assessment tools within a unified platform. The instructional approach applied was blended learning, integrating both synchronous and

asynchronous activities. In **Stage 4: Utilize Media and Materials**, the developed media was implemented across two 45-minute sessions per week over two weeks, allowing time for reflection and concept reinforcement. **Stage 5: Require Learner Participation** emphasized active student engagement through interactive quizzes, virtual laboratory simulations, drag-and-drop exercises, and collaborative live worksheets embedded within the learning media. Lastly, **Stage 6: Evaluate and Revise** was carried out via expert validation, limited trials, and full implementation, with iterative revisions informed by collected feedback. To illustrate the development research process, the ASSURE model diagram is presented in Figure 1 that shows six interconnected stages of ASSURE with a feedback loop for the ongoing revision process, covering input from learner analysis to final evaluation of interactive media products.

Research Instruments

Test Instruments

The pretest and posttest were developed to measure the effectiveness of the media in improving the understanding of the concepts of the human digestive system and excretion. The test consists of 30 multiple-choice questions.

Non-Test Instruments

Three types of questionnaires were developed using a 4-point Likert scale: (1) Expert Validation Questionnaire to assess the feasibility of content, media, and learning; (2) Teacher Response Questionnaire to measure the practicality of media implementation; and (3) Student Response Questionnaire to evaluate user experience and engagement. Each questionnaire has been expert-validated and tested for reliability using Cronbach's Alpha with a minimum value of 0.70.

Instrument Validation and Reliability

The validation of the instrument was conducted by a panel of qualified experts specializing in educational materials and media, affiliated with a public university in Indonesia. The validation process employed the Content Validity Index (CVI), with a minimum threshold of 0.80 to indicate acceptable validity. Reliability testing of the questionnaires was performed using Cronbach's Alpha, yielding the following coefficients: Expert Validation Questionnaire (α = 0.89), Teacher Response Questionnaire (α = 0.85), and Student Response Questionnaire (α = 0.87). Additionally, inter-rater agreement was evaluated using Cohen's Kappa, with a minimum acceptable value of 0.75.

Data Analysis Techniques

Validity Analysis

The validity of the developed instruments and learning media was assessed using the Content Validity Index (CVI), calculated through expert agreement. The CVI was determined using Formula I.

$$\mathrm{CV} = \frac{\mathrm{D}}{\mathrm{A} + \mathrm{B} + \mathrm{C} + \mathrm{D}} \; (Formula\ I)$$

where D represents the number of items deemed highly relevant by both experts, A represents the items rated as less relevant by both, while B and C indicate partial agreement between experts. This approach measured how consistently the experts

evaluated the relevance of each item. The interpretation of the CVI results referred to Table 1, which classifies content validity into five categories ranging from "Very Low Validity" (0.00–0.19) to "Very High Validity" (0.80–1.00) (Hakam et al., 2024). A high CVI score indicates that the media strongly meets the content, visual, and pedagogical requirements for effective instructional use.

Table 1. Validity Categories

Value Range	Criterion
0.8 – 1	Very High Validity
0.6 – 0.79	High Validity
0.40 – 0.59	Medium Validity
0.20 – 0.39	Low Validity
0.00 – 0.19	Very Low Validity

Practicality Data Analysis

The practicality of the learning media was evaluated using a quantitative approach to calculate the average practicality score. This was computed with Formula II.

$$\bar{X} = \frac{\sum_{j=1}^{n} \overline{Ai}}{n} \ (\boldsymbol{Formula\ II})$$

where $\bar{x}$ denotes the overall average score, Ai represents the score assigned to each practicality criterion, and n is the total number of criteria. Practicality was assessed through teacher and student responses using structured questionnaires. The score interpretation followed the scale in Table 2, which categorizes practicality from "Very Impractical" (0–20%) to "Very Practical" (81–100%) (Hassan et al., 2021). A high practicality score indicates that the media is user-friendly and effectively supports teaching and learning activities.

Table 2. Categories Practicality

Categories of practicality (%)	Criterion
81 - 100	Very practical
61 - 80	Practical
41 - 60	Quite practical
21 - 40	Less practical
0 - 20	Very impractical

N-gain analysis

The effectiveness of the developed media in improving student understanding was analyzed using the normalized gain (N-Gain) method. This was calculated with Formula III.

$$\text{N } gain = \frac{Posttest\ Score\ - Pretest\ Score}{Maximum\ Score\ - Pretest\ Score} \ \text{(Formula III)}$$

This formula assesses the relative improvement in student learning outcomes by comparing scores before and after using the media. The resulting N-Gain values were interpreted according to Table 3, which classifies the improvement as "Low" (N-gain < 0.3), "Moderate" (0.3 ≤ N-gain < 0.7), and "High" (N-gain ≥ 0.7) (Hake, 1999). A high

N-Gain score indicates that the learning media significantly enhanced students' comprehension of the material.

Table 3. Categories of Learning Outcomes Improvement

Interval coefficient	Criterion
N-gain < 0.3	Low
0.3 ≤ N-gain < 0.7	Moderate
N-gain ≥ 0.7	High

Ethical Statement

This research was conducted in accordance with ethical guidelines for educational research. Prior to data collection, informed consent was obtained from all participants, including parental consent for students under the age of 18. Participation was voluntary, and students were informed of their right to withdraw at any time without academic penalty. The study involved minimal risk and was limited to standard classroom practices, including the use of validated tests and questionnaires for educational evaluation purposes. All data collected were kept confidential and anonymized for analysis and reporting. The research was approved by the institutional ethics committee of SMA Negeri 3 Takalar, ensuring adherence to principles of beneficence, respect for persons, and justice.

RESULTS AND DISCUSSION

Analyzing Students

Teachers observe and interact with students to better understand their learning nature. These findings reveal that students are not interested in traditional lectures and struggle to understand how the digestive and excretory systems work together. The introduction of interactive media using visuals and animation emerged as a solution to these challenges. This is in line with the findings Ansari and Khan (2020), which highlights the importance of understanding learner characteristics to create effective media. The Ministry of Education and Culture of the Republic of Indonesia (2021) emphasizes the need for diagnostic assessments to better adapt the learning approach to the needs of students. Through these efforts, the media is designed to address this specific learning gap by incorporating more engaging and accessible content.The literature strongly supports the need for a learner-centered approach. Antonietti et al. (2023) argues that knowing the characteristics of students is essential to designing effective media.

State Objectives

Learning objectives are aligned with the Independent Curriculum, combining Learning Outcomes (CP) and Learning Objectives Flow (ATP) based on SMART principles. This framework ensures clear, measurable, and achievable goals, guiding the learning process effectively. Alobaid (2020) emphasized that setting specific and measurable goals increases the effectiveness of digital media in supporting learning. The nature of personalized learning objectives makes media more relevant to students, increasing engagement and focus.

This approach is also consistent with SMART principles, which have been shown to improve student motivation and learning outcomes (Bjerke & Renger, 2017). The

integration of personalized objectives into media design is essential to its success in engaging students and driving better learning outcomes.

Select Methods, Media, and Materials

This study uses a problem-based learning (PBL) approach, equipped with Articulate Storyline as a media tool. This combination allows the presentation of abstract content in both visual and interactive formats. The inclusion of animation, video, and text in the media follows an organized structure that enhances understanding. (Degner et al., 2022) highlighting the importance of aligning teaching methods with students' digital learning profiles, which has a direct impact on their success. This choice of methodology also supports the development of critical thinking and collaboration among students.

The literature supports the use of PBL as an effective strategy for developing critical thinking and problem-solving skills. (Diaz-Pinto et al., 2024) emphasizing the positive effects of using digital media that are in accordance with students' digital learning preferences. The use of Articulate Storyline, with its interactive and visual capabilities, has been widely recognized for its ability to enhance learning, making abstract concepts more real (Du et al., 2023). This is in line with the study's findings, showing that PBL combined with interactive media significantly improves student engagement and learning outcomes.

Utilize Media and Materials

This study applies a problem-based learning (PBL) approach supported by interactive media developed using Articulate Storyline. The selected media present abstract content through visuals, animation, and interactive elements that enhance conceptual understanding. This aligns with Mayer's (Mayer & Schwemmle, 2023) multimedia learning theory and responds to students' digital learning preferences, which are essential for effective engagement and achievement (Degner et al., 2022).

Require Learner Participation

Learners are actively involved through interactive tasks such as quizzes, simulations, and problem-solving scenarios embedded in the digital media. These activities are designed to stimulate critical thinking, collaboration, and reflection. The approach is grounded in Vygotsky's (1978) social constructivism and supported by the ICAP framework (Chi & Wylie, 2014), which emphasizes that active engagement leads to deeper and more lasting learning outcomes.

Evaluate and Revise

The product undergoes a comprehensive evaluation, which includes formative and summative assessments. Formative evaluations include validity tests, user feedback, and progress tracking through quizzes and worksheets. The evaluation process is guided by the ADDIE model (El-Sabagh, 2021), which emphasizes the importance of revisions based on real data. This stage is critical to ensure the product meets educational standards and is effective in helping students learn. Feedback from teachers and students leads to important revisions, which improve the usability and effectiveness of the media.

The revision process is in line with the approach (Hassan et al., 2021) in the ADDIE model, which emphasizes continuous improvement based on user feedback and data analysis. It is supported by (Kaur et al., 2020), which highlights that product

development in educational media should be iterative, ensuring that the final product is effective and usable. Furthermore, Clark and Mayer (2016) emphasize that valid and well-structured learning materials are essential to facilitate student learning. The results of this study validate the importance of the revision, which ultimately contributes to the success of the media in delivering content and engaging students.

Product Validity

Each validator looks at six main parts of a multimedia product: the learning object, the teaching materials, how the concepts are organized, how the display is designed, how the material is prepared, and the language. Table 4 shows a summary of the results of this assessment.

Table 4. Validation Results of Interactive Multimedia Content Based on the Gregory Test

Aspects Assessed	Gregory Value	Relevance Code	Validity Type
Learning Objects	1.00	D	Very High Validity
Teaching Materials	1.00	D	Very High Validity
Organizing Concept	1.00	D	Very High Validity
Media Design	1.00	D	Very High Validity
Ingredient Preparation	1.00	D	Very High Validity
Language	1.00	D	Very High Validity
Total Average	**1.00**	D	**Very High Validity**

All aspects are rated 1.00 by the Gregory index, which is the highest value on this scale. Content validity assessment is carried out using a 4-point Likert scale (1 = invalid, 2 = less valid, 3 = valid, 4 = very valid) to ensure the clarity of the gradation gradation and avoid the central tendency bias that often occurs on odd scales. The selection of this even scale is in line with the recommendation of Wiersma and Jurs (2009) that even scales force respondents to take a definitive position on the object being assessed, resulting in a more firm and objective assessment.

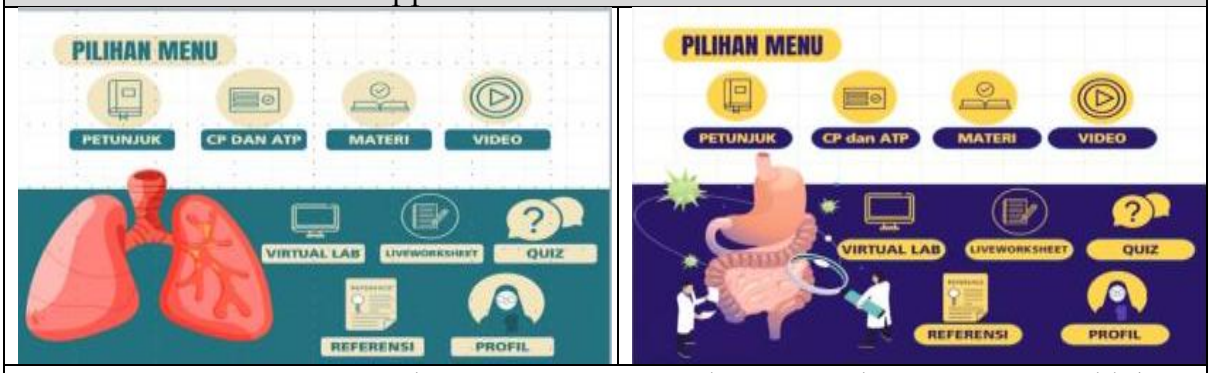
According to Hair et al. (2019), an index value of 1.00 is only achieved when both validators give a positive rating (score 3-4) on all items, without any negative rating (score 1-2) from either validator. These results show that the media has met very high standards of content validity. Comparison with other biology learning media shows that the Gregory Index score of 1.00 obtained is included in the superior category. Study by (Kolhar et al., 2021) in the development of Android-based learning media obtained a Gregory Index of 0.83, while the research (Kaur et al., 2020) About the Biology Virtual Laboratory reached an index of 0.88. The superiority of the validity of this content can be attributed to the systematic development process using the ASSURE model and multiple revision cycles based on expert feedback before the final assessment.

The validator also provided a positive assessment of the pedagogical aspects of the media, especially the implementation of scaffolding learning and formative assessment that are integrated in each learning module. This means that both validators agree completely (Li & Wen, 2024). Based on these results, multimedia

products were found to be very valid and good to be used as a learning tool in high school/MA grade XI on material on the digestive system and the human excretory system. Study by Liao et al. (2024) supports this research by saying that the Gregory test is one of the best and most recommended ways to check the validity of content in development research, especially when only two experts are involved. In practice, a Gregory value of 0.80 or higher is already considered valid. So, getting a value of 1.00 indicates that the validated aspect is of high quality.

Liono et al. (2021) stated that high content validity is important when creating learning media to ensure that the material is in line with the curriculum and that information is delivered clearly, accurately, and effectively. Figure 2 shows the results of the application revision.

App Front View

The title of the chapter of the material is accompanied by an image icon according to the chapter title, the application login button, and the campus logo of the State University of Makassar
Application Menu Selection View

instruction menu, CP and ATP menu, material menu, video menu, virtual lab menu, liveworksheet menu, quiz menu, reference menu and creator profile menu
Videos for Learning

Animated video of the human digestive system and excretory system.

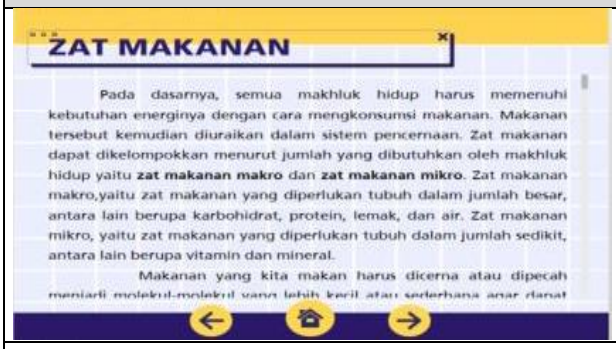
Liveworksheet Menu for Apps

Student online worksheets that are presented interactively on the material of the digestive system and the human excretory system

Virtual Lab Menu

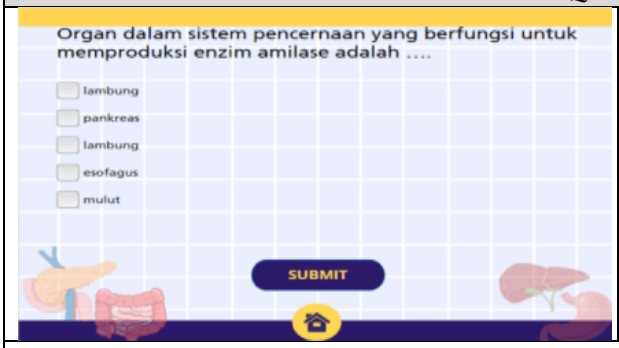
An online practicum experiment simulation that can help students practice directly in the lab

Material Content Display



Substances of the digestive system and the human excretory system

Interactive Quiz Menu View



Multiple-choice quizzes and quizzes match terms presented interactively and display scores at the end of the quiz

App Developer References and Profiles

Literature references in app development and brief biodata by app developers.

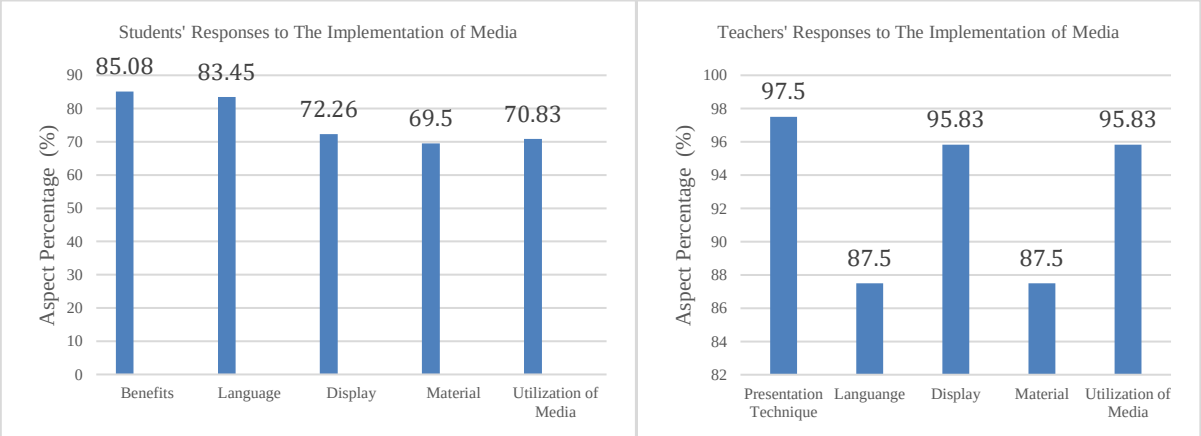
Figure 2. Interactive Media Display

An in-depth analysis of the impact of each component of interactive media shows a different contribution to improving student learning. The virtual lab menu developed using PhET simulations and HTML5 interactives showed a significant impact on student engagement, with an average interaction rate of 89.3% compared to 65.2% in conventional static media. The interactive liveworksheet menu shows a positive impact on formative assessment and self-regulated learning. A total of 34 students produced a total of 71 submissions on the interactive worksheet. This shows that each student makes an average of 2.09 attempts to complete an assignment, which reflects the students' efforts to repeat and improve their work.

The Evaluation and Revision stage of the ASSURE model shows that the development process is carried out in a planned manner. At this point, expert feedback is used to improve the product before it is used in real terms (Branch, 2009; Smaldino et al., 2019). From a learning theory standpoint, valid content helps people learn well. The information is structured and based on learning objectives, so Clark and Mayer (2016) says that a valid learning medium will help the brain work better. Learning media is only valid if you get at least one validation result in the "good" category (Juniantari & Santyadiputra, 2021). If it gets a lower validation value, it needs to be changed. This product is eligible for the implementation or field trial stage because it has reached a "very high" level. Expert evaluations show that interactive multimedia using the Articulate Storyline app has a very high content validity and has been improved over time. This validity is an important part of ensuring that the media is of high quality overall and is more likely to be useful for learning biology.

Media Practicality

The practicality of interactive multimedia is assessed based on user responses, namely teachers and students after using media in the learning process. Data were obtained through a questionnaire arranged on a percentage scale and presented in Figure 3. The results in Figure 3.a show that students rated the benefits (85.08%) and language aspects (83.45%) as very practical (range 81-100%), while the aspects of display, materials, and use were in the category of practice (range 61-80%). Meanwhile, the results in Figure 3.b show that teachers scored above 87% in all aspects, which means being in that category is very practical. The practicality of media can be assessed from two main angles: convenience and usefulness (Zolkepli & Kamarulzaman, 2015).



a. Students' Practical Responses b. Students' Practical Responses

Figure 3. Practical Responses of Students and Teachers

Based on the findings (Figure 3), the multimedia developed provides real benefits in the learning process and is easy to use by teachers and students. Learning media is said to be practical if it receives a positive response from at least 81% of users, and does not pose any technical barriers to use (Nuryakin et al., 2023). In addition, this media has interactive features such as hands-on worksheets, formative quizzes, and virtual labs that improve the quality of self-paced learning. This supports the claim that when students can learn on their own without the help of a teacher, the practicality of multimedia increases significantly (Haleem et al., 2022; Palaigeorgiou & Papadopoulou, 2019; Vaičiūnienė & Kazlauskienė, 2023). The results show that Articulate Storyline 3-assisted interactive multimedia is very practical for F-phase biology learning in high school/MA, both in online and offline models.

Media Effectiveness

The effectiveness of media is measured through student learning outcomes before and after using multimedia. The effectiveness test was carried out using the N-Gain formula, which compared the pretest and posttest scores of 34 students in grade XI (see Table 5).

Table 5. Student Scores, Learning Completeness, and N-Gain

Category	Description	Pretest (%)	Posttest (%)
Score Range	90–100	0.00	8.82
	80–89	0.00	44.11
	70–79	0.00	17.64
	60–69	0.00	23.52
Completeness	Complete	–	82.35
	Incomplete	–	17.64
N-Gain Statistics	Minimum	–	26.09
	Maximum	–	88.89
	Mean	–	72.27
	Std. Deviation	–	13.99

A more in-depth analysis of the distribution of N-Gain showed that 26 of 34 students (76.47%) achieved an N-Gain score above 0.7, while 6 students (17.65%) were in the moderate gain category (0.3-0.69), and only 2 students (5.88%) obtained a low

gain. This distribution indicated the consistency of media effectiveness in the majority of study subjects, with relatively low variability (SD = 0.13992). This distribution pattern is in line with the findings of Sundayana (2014) which states that interactive learning media tends to produce more homogeneous improvements than conventional methods.

To verify the research hypothesis regarding the effectiveness of the developed interactive media, an inferential statistical analysis was carried out using paired sample t-tests on students' pretest and posttest score data. This test aims to determine whether there is a significant difference in the achievement of learning outcomes before and after the implementation of Articulate Storyline-based learning media with the ASSURE design. The results of the statistical analysis are comprehensively presented in Table 6.

Table 6. Paired T-Test Results

Parameters	Value
Test Statistics	t-count = 15.847
Significance	p-value < 0.001
Confidence Level	α = 0.05
Effect Size (Cohen's d)	2.71
Category Effect Size	Large Effect (d > 0.8)
N-Gain	0.7227

Based on inferential statistical analysis using paired sample t-test, a t-calculated value of 15.847 was obtained with a probability of error (p-value) of less than 0.001, which is substantially smaller than the level of significance set (α = 0.05). These findings indicate the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1), which states that there is a significant difference between pretest and posttest scores after the implementation of Articulate Storyline-based interactive media. In line with the result, previous studies has reported the integration of multiple media elements (video, animation, simulation, and interactive quiz) that accommodate various learning students' styles significantly impact on academic performance (Abdulrahaman et al., 2020; Strojny & Dużmańska-Misiarczyk, 2023).

Systematic comparison with previous empirical research shows the position of this research in the context of the development of technology-based biology learning media. Study (Syuhada & Risnawaty, 2022) about the implementation of the ASSURE model with Articulate Storyline in chemistry learning reported an N-Gain of 0.67 with a sample size of 28 students, while this study achieved an N-Gain of 0.7227 with 34 students. This difference can be attributed to the characteristics of biological materials that are more visual-friendly than abstract chemical concepts, as well as the more extensive implementation of virtual laboratories in this study. Comparative study with (Van Den Beemt et al., 2020) who developed an interactive media digestive system using Adobe Flash showed some significant methodological differences. Although both used a quasi-experimental design, Putri's study used a control group design with an experimental group's N-Gain of 0.65 versus a control of 0.23, while this study used a one-group pretest-posttest with an N-Gain of 0.7227. The superiority of this result can be attributed to the technological advancement of Articulate Storyline

which provides more interactive elements and mobile-responsive design than the obsolete Adobe Flash.

A meta-analysis of 15 studies implementing the ASSURE model in science learning (2018-2023) showed an average N-Gain of 0.64 ± 0.12, placing the study in the 78th percentile in the distribution of effectiveness. Factors that contribute to this superiority include: (1) systematic instructional design with detailed learner analysis, (2) comprehensive multimedia integration, and (3) extensive formative evaluation during the development phase. These results confirm that adherence to instructional design principles consistently results in superior learning outcomes. Comparisons with international studies show the consistency of findings across cultural contexts. Study by (Wang et al., 2023) in Malaysia on interactive multimedia in biology reported Cohen's effect size d = 2.1, which is close to the value of d = 2.71 in this study. This similarity indicates that the effectiveness of interactive multimedia in biology learning has universal applicability that is not limited to the local context of Indonesia.

(Kolhar et al., 2021) states that the best way to know how useful media is is to look at how well it helps people achieve their learning goals. According to (Antonietti et al., 2023), the school's Learning Goal Achievement Criteria (KKTP) met the classical completeness requirements (>80%). In addition, the steps in the learning implementation questionnaire must be followed during the learning process in order to work well and most efficiently.

Teachers should be able to use Articulate Storyline well, but they also need to know how to use it for learning. Articulate Storyline has many interactive features that make learning materials engaging and adaptable. But teachers can only use this feature to the fullest if they know how to use the app well. (Petersen et al., 2022) further argue that teachers need to know how to use technology properly in order to use learning technology successfully. So, to make technology-based learning better, it is important for teachers to get training and professional development in multimedia tools like Articulate Storyline.

CONCLUSION

This study demonstrates that the development and implementation of interactive multimedia using Articulate Storyline, structured through the ASSURE instructional design model, significantly enhances the learning outcomes of Grade XI students in the subject matter of the human digestive and excretory systems. The product achieved very high content validity (Gregory Index = 1.00), indicating strong alignment with pedagogical standards, curriculum content, and instructional quality.

The media also demonstrated high practicality, receiving positive responses from both teachers and students, highlighting its ease of use, visual appeal, and pedagogical effectiveness. The effectiveness analysis revealed a substantial improvement in student performance, with an average N-Gain score of 0.7227 and a large effect size (Cohen's d = 2.71), confirming the instructional impact of the multimedia intervention.

RECOMMENDATIONS

The findings affirm that the integration of interactive digital tools with systematic instructional design provides a powerful framework for enhancing student engagement and conceptual understanding in biology education. This multimedia

product not only aligns with the characteristics and learning preferences of digital-native learners but also contributes to the broader goals of educational transformation through technology. Future applications and broader implementation of this approach are recommended, particularly in supporting Indonesia's digital curriculum and achieving inclusive, high-quality science education.

Author Contributions

Each author has read and approved the published version of the manuscript, has contributed sufficiently to the study, and agrees with the findings and conclusions.

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Conflict of interests

The author declares that there are no conflicts of interest in this study.

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