



Development of an e-comic on biotechnology materials in high school

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ARTICLE INFO

Article history

Received: 10 October 2025

Revised: 12 January 2026

Accepted: 26 July 2026

Keywords:

Digital learning media

Learning innovation

Student response

ABSTRACT

Biology learning in biotechnology materials already incorporates practical activities, but the limitations of the media and visual representations remain obstacles to students' understanding. Therefore, media development e-comic potentially facilitate learning through a combination of interesting images, text, and stories. This research aims to determine students' eligibility and responses to the media e-comic, which includes biotechnology materials, as well as to explore its potential as an attractive educational resource. This research uses a modified research & development methodology based on Borg & Gall, adapted by Sugiyono. Selecting participants through purposive sampling, involving 20 tenth-grade high school students. This research uses validation sheets and student response questionnaires. The research instrument was validated by 5 expert validators. Using Aiken's V formula to analyze the data collected during the study. Reliability testing using intraclass correlation coefficients. Assessment of student response questionnaires using the Likert scale. Media validation analysis obtained an average value of 0.92, which is included in the valid category. Reliability test showing a reliability value of 0.946, which belongs to the excellent category. The assessment of student responses had an average score of 78.63%, indicating a good category. These results show that the media e-comic biotechnology materials received a positive response from students, and the media e-comic was effectively used in the learning process.

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INTRODUCTION

The quality of learning processes and outcomes is always related to each other (Qammaddin, 2021; Yurdugül & Cetin, 2015). The quality of a good learning process plays an important role in success in achieving educational goals (Siregar et al., 2021; Paramita et al., 2018). There are several factors that influence the way to produce a quality learning process, namely teaching, the use of interesting learning methods, and varying student learning behavior, conducive learning conditions and atmosphere, as well as the use of innovative learning media as a support in the teaching and learning process itself (Siregar et al., 2021). Learning media is an important component of the learning process; it also helps motivate and communicate with students more effectively. An effective learning process is a form of teaching that can create high-quality learning.

Technology-based learning media can effectively and efficiently facilitate the learning process (Firmadani, 2020). Various technology-based learning media are used to support the learning process (Shintawati, 2023). The types of learning media are visual, audio, and audiovisual. Visual media is the most common and frequently used type of learning media. The types of visual media include images, sketches, diagrams, posters, graphs, books, flip charts, and comics. One form of technology-based visual learning media that teachers can apply is e-comics (Aini et al., 2025).

E-comic is a learning aid that conveys material in the form of illustrated story text, displayed through characters in digitally packaged comics (Juneli et al., 2022). E-comics are a simple form of comics packaged and presented on electronic media (Aini et al., 2025). E-comics are comics presented through digital media such as websites known as webcomics, online comics, or internet comics (Alricoh et al., 2021; Hidayah et al., 2017). Media e-comic is a visualization of the story in the form of neatly arranged and meaningful cartoon images presented via a computer application (Zakiyah et al., 2022). Media e-comics can improve students' reading skills by building on students' reading interests, reading habits, and ability to retell what they have read (Willya et al., 2023).

In the context of education in Indonesia, teaching natural sciences, especially biology, poses its own challenges, particularly with complex materials such as biotechnology (Fahira & Puspitawati, 2025). Biotechnology materials that are complex and require a deep understanding are often challenging for students. This condition is increasingly difficult due to the limited availability of learning resources, such as textbooks, teaching methods, and learning media (Hadianty et al., 2025). Biotechnology materials have several characteristics, including multidisciplinary knowledge, applicability, and abstraction, so they require sufficient mastery of basic concepts. From literature studies, opinions were found that biotechnology materials have caused significant controversy, especially regarding GMO products. However, given the multidisciplinary, applicative, abstract, and controversial nature of biotechnological materials, they have developed rapidly because their benefits are directly related to improving the quality of human life (Sulistyowati & Roshayanti, 2022). The scope of biotechnology includes conventional biotechnology, for example, making tempeh, tape, and bread, while modern biotechnology includes tissue culture, animal cloning, and genetic engineering (Khazalina, 2020). Several efforts have been made to overcome the difficulties of biotechnology materials by developing learning media such as modules (Fitriani et al., 2017), e-booklets (Marcellina et al., 2023), electronic modules (Wahyuniasti et al., 2022), textbooks (Duda et al., 2022), and digital comics (Fitriani et al., 2023).

Digital comics are interactive works that combine illustrated stories and digitally produced text (Zakiyah et al., 2022). Digital comics combine narrative text, visual illustrations, and interactive elements to attract students' attention (Aini et al., 2025). Digital comics have tremendous power to convey information visually, making them easier for readers to understand and remember (Pratama, 2018; Sari et al., 2025). Digital comics are also very effective at simplifying complex material, making it easy for students to understand. From literature studies, opinions were found that digital comics have the advantage of presenting contextual storylines, making it easier to understand abstract concepts, and can be adapted to local cultural contexts (Saqjuddin & Saputra, 2025). This makes the learning process easier because students can connect the material with their concrete experiences. So, in the context of biotechnological materials, which often involve abstract, complex concepts that require visual understanding, this digital comic medium is well-suited for deep understanding.

So far, previous research on using e-comics as a medium for biological learning, Pinatih & Putra (2021) research shows that e-comics, based on a scientific approach, have an attractive appearance

because they combine a balanced combination of images, colors, and text, and are practical and easy to access in use. Another advantage of this media is its cover design and illustrations, which reflect the e-comic's overall content, thereby encouraging students' interest in reading and understanding the learning concepts presented. Furthermore, research conducted by Ranting & Wibawa (2022) shows that media e-comics should be used as a learning medium because they can attract students' attention through visually appealing presentations. Media e-comics developed have the advantage of displaying color illustrations, simple storylines, and easy-to-understand language, making students more receptive to the material presented. Apart from that, the interactive visual appearance makes students more focused and motivated to learn. Research by Lestiani et al. (2021) on the development of a media e-comic on virus danger in this biology subject shows that media e-comics that combine images, text, colors, and dialogue, packaged into a storyline, are effective in helping students understand material on viruses. Thus, this research demonstrates that media e-comics are feasible and effective for biological learning. Maharani & Fernandes' previous research (2022) examined the urgency of e-comic media for learning sociology in high school, namely, students' habits and their need to understand the material without memorizing it, making e-comic learning very necessary. This aligns with the research results, which show that students strongly agree with using media e-comics in learning because they prefer learning accompanied by illustrated conversations.

Based on a background review of the problems above, one step to make it easier for students to understand biotechnology material is to create a learning process that is fun and not boring, using alternative learning media to support it. This research was conducted to assess the feasibility of e-comics on biotechnology materials and to determine students' responses to media e-comics. And media development e-comic, this will provide innovative solutions to improve the quality of biological learning, especially in biotechnology materials.

METHODS

Research Design

This research employs a Research and Development (R&D) approach, using the models of Borg and Gall. According to Nawali et al. (2024), Borg and Gall offer comprehensive measures that can be modified to meet research needs, yielding valid and effective data. One of the main aspects of this model is a focus on a deep understanding of learning needs. The stages Borg and Gall used in this research are modified stages (Sugiyono, 2021). In Sugiyono (2021) approach research and Development (R&D) consists of ten stages, namely identifying potential and problems, data collection, product design, design validation, design revision, product trial, product revision, use trial, product revision, and mass production of products. However, this research follows seven stages: potential and problems, data collection, product design, design validation, design revision, product trial, and product revision.

Population and Samples

Population refers to all research subjects or objects that have certain characteristics that are the focus of research (Ramadani et al., 2025). The study population was class X students at SMA Islamiyah Pontianak, West Kalimantan. The determination of schools is based on criteria, namely, schools located in Pontianak and implementing an independent curriculum. This research uses purposive sampling. Engineering purposive sampling, namely, sampling techniques that consider specific criteria. Sample selection is based on specific criteria or ease of access, not on random methods (Subhaktiyasa, 2024). The sample used for testing consisted of 20 participants who completed a response questionnaire. Before the questionnaire is distributed to students, it is first validated by five validators, comprising two biology lecturers and three biology teachers. The sample selection is based on the characteristics of students who have studied biotechnology material, so that students understand the principles and concepts of biotechnology material in general.

Instruments

The instruments used in this study included validation sheets and student response questionnaires. The validation process is carried out by five validators. According to Hafidzah et al. (2021), there are three main aspects of content suitability: the suitability of the material to competency standards (KI), the accuracy of the material, and the suitability of the learning support material. According to Handayani (2021), presentation eligibility includes components of presentation techniques, presentation of learning, and coherence of thought flow. According to Telaumbanua & Zega

(2023), the language used must be in accordance with Indonesian language rules, easy to read, and communicative. In line with previous studies, the media validation of e-comics assessed content, presentation, and language eligibility.

The aspects of the feasibility of the contents on the validation sheet of this research include the suitability of the material for learning achievement, the accuracy of the e-comic, as well as its functional characteristics and supporting components. The feasibility of the content indicator of the suitability of the material to learning achievement comprises five sub-indicators. The feasibility of content on the material accuracy indicator on e-comic includes four sub-indicators. The feasibility of the content on indicators, functional characteristics, and supporting components of the e-comic is assessed using five sub-indicators. Aspects of presentation feasibility include the harmony of the composition of the layout elements and the drawings in e-comic; the combination of matching font size and font size can be read well; the combination of font types on e-comic, matching and precise letter variations; matching color combinations on e-comic; and the distance between text and illustration on e-comic is harmonious. The feasibility of presenting indicators of harmony in the composition of the layout and the drawing in the e-comic includes two indicators. The feasibility of the presentation on indicators, including the combination of matching font sizes and a well-readable font size, is demonstrated with one sub-indicator. The feasibility of presenting the combination of font types for e-comic matching and precise letter variations is evaluated using two indicators. The feasibility of presenting indicators in color combinations on an e-comic includes one sub-indicator. Feasibility of a presentation on indicators, the distance between text and illustration in the e-comic, and matching, including one sub-indicator.

Aspects of language eligibility include language in e-comic simple and easy to understand; language on e-comic not convoluted and conveying information clearly; language on e-comic in accordance with students' abilities and using sentence structures in accordance with the General Guidelines for Indonesian Spelling; and the terms used in e-comic according to the Dictionary Big Indonesian. The language indicators in the e-comic are simple and easy to understand, with three sub-indicators. The language of the indicators pada language e-comic is not convoluted and conveys information clearly, including two sub-indicators. Language feasibility of indicators pada language e-comic in accordance with students' abilities and using sentence structures in accordance with the General Guidelines for Indonesian Spelling includes one sub-indicator. Language feasibility of indicator terms used in e-comic in accordance with the Big Indonesian Dictionary, which includes one sub-indicator. Student responses include cognitive, affective, and conative aspects (Amir, 2015). In this study, the student response test questionnaire assessed three aspects: affective, cognitive, and conative. Affective aspects include motivation and attractiveness. Cognitive aspects include clarity of instructions for use of the e-comic and suitability of its appearance. Conative aspects include behavior.

Procedures

This research consists of seven stages: potential and problems, data collection, product design, design validation, design revision, product trials, and product revision. The first stage is potential and problems. According to Juneli et al. (2022), digital comic media can be an effective learning tool to support learning achievement and increase student motivation and participation in the learning process. According to Sari et al. (2025), the use of appropriate and engaging learning media can provide students with opportunities to improve their learning. According to Pratama (2018), media e-comics have excellent visual skills in presenting information, making it easier for readers to understand and remember. The potential of this research is that e-comics can improve learning outcomes, motivate and increase participation, and make learning easier to understand and remember, thanks to media visualization, which makes e-comics more engaging. In Indonesian education, teaching natural sciences, especially biology, poses its own challenges, particularly with complex materials such as biotechnology (Fahira & Puspitawati, 2025). The problem is analyzed by doing needs analysis, student characteristics analysis, and curriculum analysis.

Needs analysis stage: interview teachers to identify problems with the use of learning media in biotechnology materials. The results of the interview showed that the lessons learned had applied tempeh-making practices, but the fermentation results were not optimal due to limited access to digital technology, the unavailability of LKPD, and the absence of demonstration videos of tempeh-making steps. The characteristic analysis stage is used to understand students' intellectual abilities and social skills, which are then developed to achieve learning goals. During the characteristic analysis stage, it

was found that the students in class X at the high school ranged in age from 15 to 17 years. According to Piaget's theory, the formal operational stage spans the age range from 11 years to adulthood, with a more abstract, logical, and idealistic way of thinking. In developing their intellectual skills, students integrate what they have already experienced with theories or concepts, such as those related to biotechnological materials. The curriculum analysis stage was carried out to examine the characteristics of the school's curriculum. This is done to determine the learning objectives and the scope of the material to be used as a reference for developing learning media. The learning goal flow used is in accordance with the independent curriculum for class X of high school.

The data collection phase includes literature studies and field studies. Literature studies are carried out to analyze the flow of independent curriculum learning objectives based on learning achievements and learning objectives. The material to be used is biotechnology material. Field studies aim to collect data directly from real-world settings relevant to the research topic.

The learning media design stage includes developing product specifications, namely a media e-comic on biotechnology materials that can serve as alternative learning resources. The application used to design this product is Canva. Used Google Site website software as a website to accommodate e-commerce, as well as other sources from the internet. The e-comic contains general biotechnology material, the stages of plant tissue culture, and applications of biotechnology to the tempeh-making process. E-comics can also be accessed online through the Google website or offline by downloading comics in PDF form from the Google website. The presentation e-comic focuses on images and text (visual and informative) and includes a QR code with material and practice questions.

Media design validation phase e-comic performed by five validators, the instrument used is a validation sheet. The validation sheet e-comic consists of three aspects, namely content eligibility, presentation eligibility, and language eligibility. After receiving feedback from the validator, a media revision stage is carried out based on the expert validator's assessment. Media e-comic, which was deemed worthy by the validator, then underwent a trial phase with class X students at SMAS Islamiyah Pontianak. After conducting trials with students, a further revision phase was carried out to improve the media quality of the e-comic.

Data Analysis Techniques

The validation data is then analyzed to assess the feasibility of the e-comic. The aspect assessed comprises three components: content, presentation, and language. Assessment was performed using the Likert scale. The Likert scale is used to measure attitudes, opinions, and perceptions of individuals or groups regarding research variables (Sugiyono, 2021). Validation sheet assessed by the validator by providing a mark checklist in one of the value choices consisting of 4 categories, namely 4 (very good), 3 (good), 2 (not good), and 1 (not good). Additionally, validate the e-comic analyzed using Aiken's V (Aiken, 1985).

The instrument is declared valid if Aiken's V is equal to or greater than 0.87. This criterion was determined by involving five validators, who provided assessments using four ranking categories, with a significant rate of 5% ($\alpha = 0.05$). After the media e-comic is declared valid, a reliability analysis is required to assess consistency across validators. Reliability analysis was carried out using the Intraclass Correlation Coefficients (ICC) method in IBM SPSS Statistics 26. Referring to Koo & Li (2016), the model used is a two-way mixed effects model with multiple raters and definitions of absolute agreement. Intraclass Correlation Coefficients (ICC) were chosen because the method is suitable for measuring inter-rater reliability in subjective assessments. According to Arum et al. (2022), instruments are declared reliable if the ICC value is equal to or more than 0.75 and the p-value is less than 0.05. Once the instrument meets the validity and reliability requirements. Then, student response data were collected using a response test questionnaire. The questionnaire used in this research is closed-ended. According to Aryandi & Onsardi (2020), a closed questionnaire is one in which respondents are asked to choose an answer that best fits their characteristics by marking a checkbox. In this study, student responses were assessed using a 4-point Likert scale with the following options: strongly disagree (STS), disagree (TS), disagree (KS), and strongly agree (SS). According to Kartini & Putra (2020), after all the student response questionnaire data is recapitulated and calculations are carried out for each statement item. Next, the student's response to the media was classified by comparing percentage results with positive criteria.

RESULTS AND DISCUSSIONS

According to Pratama (2018), learning media serve as a means of conveying messages that help students understand the material, enabling optimal achievement of learning goals. According to Firmadani (2020), learning media are one of the components that support the effectiveness of the learning process. According to Shintawati (2023), the use of appropriate media in the learning process can increase students' motivation to engage with and deepen their understanding of the material being taught. This research produces biotechnology e-comic media that aims to make it easier for students to achieve learning goals and understand the material more effectively, and can be accessed on digital devices at any time. The e-comic is presented as a website that includes instructions for use, learning objectives, and achievements, along with an attractive visual design and supporting practice questions. The e-comic structure consists of a start page, three biotechnology submaterials, and a cover section that includes a glossary, references, the development team, and a comic access and evaluation QR code.

Results of media development research on e-comic biotechnology materials focus on two aspects: media feasibility, assessed by validators, and student responses after using the e-comic. Below are presented the results of the analysis of these two aspects.

1. Validation E-comic On Biotechnology Materials

According to Fitriani et al. (2023), validation is conducted to assess the feasibility of an instrument or learning device before it is used in trials. According to Zakiyah et al. (2022), learning media should be valid before being used in the learning process. The validation process in this research aims to assess the quality and feasibility of the media e-comic before it is used by students in the learning process. This validation covers three aspects of the assessment, namely content appropriateness, presentation appropriateness, and language appropriateness. The validation results for the e-comic in the biotechnology material are presented in Table 3.

Table 3

Validation results of the e-comic on biotechnology materials

Aspect	Indicator	Sub Indicator	Aiken's V	Description
Content Feasibility	Suitability of material to learning achievements	Material on e-comic in accordance with learning indicators	0.93	Valid
		Material on e-comic can be understood without help e-comic another	0.93	Valid
		Learning indicators on e-comic in accordance with learning objectives	0.87	Valid
		Subchapter on e-comic arranged systematically	0.93	Valid
		E-comic learning has instructions for use	0.93	Valid
	Accuracy of material on e-comic	Concept on e-comic according to experts	0.87	Valid
		Theory on e-comic in accordance with the theory of experts	0.87	Valid
		E-comic developed in accordance with developments in science and technology	0.93	Valid
		The image presented in e-comic support learning materials	0.93	Valid
	Functional characteristics and supporting components e-comic	E-comic flexible to use in various hardware	0.93	Valid
		E-comic easy to access on various hardware	1.00	Valid
		E-comic easy to operate	1.00	Valid
		E-comic learning has a glossary of terms	1.00	Valid
		E-comic have self-assessment to	0.93	Valid

Aspect	Indicator	Sub Indicator	Aiken's V	Description
		measure students' abilities		
	Total		0.93	Valid
Presentation Feasibility	Compatibility of layout element composition (title, author, illustration, and logo) and image on e-comic	Compositional compatibility of layout elements (title, author, illustration and logo)	0.87	Valid
		Compatibility of the elemental composition of the matching image layout	0.93	Valid
	The combination of matching font sizes and font sizes can be read well	Compatibility of letter size combinations	0.87	Valid
	Combination of fonts on e-comic matching and variations of letters (bold, italic, capital) the right one	Matching typeface combinations	0.93	Valid
		Letter variations (bold, italic, capital) exactly	0.87	Valid
	Matching color combinations on e-comic	Matching color combinations	0.87	Valid
	Distance between text and illustrations on e-comic harmonious	The distance between text and illustration is compatible	0.87	Valid
	Total		0.89	Valid
Language Feasibility	Deep language e-comic simple and easy to understand	Language use on e-comic simple	0.93	Valid
		Language use on e-comic easy-to-understand	0.93	Valid
		Language use on e-comic according to student abilities	1.00	Valid
	Language on e-comic not complicated and can convey information clearly	Language use on e-comic not convoluted	0.87	Valid
		Language use on e-comic can convey information	1.00	Valid
	Language on e-comic in accordance with students' abilities and using sentence structures in accordance with the General Guidelines for Indonesian Spelling	Use of sentence structure in accordance with the General Guidelines for Indonesian Spelling (PUEBI)	0.87	Valid
	Terms used in e-comic in accordance with the Big Indonesian Dictionary	Use of terms in e-comic in accordance with the Big Indonesian Dictionary (KBBI)	0.87	Valid
	Total		0.92	Valid

a. Feasibility aspects of the contents

According to Hafidzah et al. (2021), there are three main aspects of content suitability: the suitability of the material to competency standards, the accuracy of the material, and the suitability of the learning support material. Aspects of content feasibility in the media e-comic include three indicators: the suitability of the material for learning outcomes, the accuracy of the material, and functional characteristics and supporting components. Overall, the content feasibility aspects have an average Aiken's V of 0.93, indicating a valid category.

The first indicator is translated into five sub-indicators. In the first sub-indicator, namely the material on e-comic, in accordance with learning indicators, Aiken's V validation value of 0.93 was obtained with valid categories. This value is obtained because the material prepared aligns with learning indicators, which are important characteristics of e-comics. Handayani (2021) states that preparing material aligned with basic competencies and indicators can make it easier for teachers to determine the scope of material to be taught to students, ensuring that the material provided is not general.

Sub the second indicator is material on e-comic can be understood without help, e-comic, another that is, a validation value of 0.93 with valid categories was obtained because the presentation of the material is contextual and easy to understand. As per Hafidzah et al. (2021), comics present sequential visual messages accompanied by narrative text, making them interesting and easy for students to understand. Sub the third indicator is the learning indicator on e-comic in accordance with the learning objectives, a validation value of 0.87 with valid categories was obtained, with biotechnology materials adapted to the flow of learning objectives. This aligns with Firmadani (2020) view that the planning stage is crucial for creating a learning process that runs optimally and enables the achievement of learning goals.

The fourth sub-indicator is the sub-chapter on e-comic systematically arranged, a validation value of 0.93 with valid categories was obtained. Value is derived from the logical organization of the material, starting with basic concepts, followed by detailed explanations and real examples from everyday life. The learning flow must be logically structured and well structured, starting from basic concepts to more complex levels. Firmadani (2020) states that engaging learning media offers innovative and diverse ways to present their material.

The fifth sub-indicator, e-comic learning, has instructions for use, namely obtaining validation results of 0.93 with valid categories. Values are obtained through the media e-comic, which includes instructions for use, making it easier for students to understand how to use it. According to Telaumbanua & Zega (2023), e-comics designed are they can to serve as a learning medium in the learning process.

The material accuracy indicator on e-comics consists of four sub-indicators. The sub-indicator of conformity of the concept with expert studies obtained a validation value of 0.87 (valid category), because biotechnology material is presented accurately and contextually through examples of everyday life that encourage students' critical thinking skills, as is the demand for learning in the digital era (Doyan et al., 2024). The theoretical suitability sub-indicators also obtained a validation value of 0.87 (valid category), as demonstrated by the presentation of scientific theories, such as cell totipotency at the tissue culture stage. This statement is supported by Pratama (2018) which emphasizes that learning media plays a role in increasing knowledge, forming attitudes and developing students' skills.

The third sub-indicator shows that e-comics are developed in line with scientific and technological advances, with a validity value of 0.93 (valid category), as they incorporate modern biotechnological methods such as genetic engineering and biofortification, which are relevant to current scientific developments (Qammaddin, 2021). The fourth sub-indicator shows that the image in the e-comic supports the learning materials, with a validation value of 0.93 (valid category), as evidenced by appropriate illustrations, such as the stages of making tempeh and the tissue culture process, to clarify the material. Based on the validator input, improvements were made to the image display to make it clearer and more premium. According to Paramita et al. (2018), learning activities must be designed to achieve learning goals.

The third indicator, namely functional characteristics and supporting components of e-comics, consists of five sub-indicators. The first sub-indicator, flexible e-comic, is supported on various hardware devices, achieving a validation value of 0.93 (valid) because it can be accessed on smartphones, laptops, and tablets without reducing display quality. The second sub-indicator, e-comic, is easily accessible on various hardware devices, obtaining a validation value of 1.00 because a QR code is available. The third sub-indicator, e-comic, is easy to use, with a validation value of 1.00 due to its clear, interactive navigation. This aligns with Juneli et al. (2022), who stated that digital media makes learning more flexible and contextual. The fourth sub-indicator, e-comic, includes a glossary of terms, yielding a validation value of 1.00, making it easier to understand biotechnology terms. The fifth sub-indicator, e-comic, has a self-assessment, obtaining a validation score of 0.93 because it provides practice questions to measure students' understanding. This is supported by Qammaddin (2021), who states that evaluation is used to assess the effectiveness and efficiency of learning.

b. Feasibility aspects of presentation

According to Handayani (2021), the feasibility of presenting in validation includes presentation techniques, presentation of learning, and coherence of thought flow. The feasibility of presenting e-comic media comprises five indicators: layout and image harmony, readability and font size harmony,

font type and variety harmony, color combination harmony, and distance harmony between text and illustrations. Overall, this aspect had an Aiken's V average of 0.89, with valid categories.

First indicator: harmony of composition of layout elements (title, author, illustration, and logo) and images, consisting of two sub-indicators. The layout element composition compatibility subindicator obtained a validation value of 0.87 (valid) because the arrangement of the title, author name, illustration, and logo was systematic and structured, without interfering with the e-comic text. This aligns with Willya et al. (2023), who stated that digital comics with attractive visual displays and structured layouts can increase students' interest in reading and enthusiasm.

The second sub-indicator, namely the harmonized composition of the elements of the harmonized image layout, obtained a validation value of 0.93 with valid categories. The images are arranged with a balanced distance and position, thereby clarifying the story's content and the material in the e-comic. Based on the validator's assessment, improvements are needed in the title of character and character recognition. Improvements in the arrangement of traits and roles in characters. According to Shintawati (2023), good design is not only informative but must also be able to attract students' attention and increase their involvement in the learning process.

The second indicator is a combination of font size and readability, consisting of one sub-indicator. The letter size combination compatibility sub indicator obtained a validation score of 0.87 with valid categories because the letter size is adjusted to the writing level, neither too small nor too large, and differences in the size of the title, subtitle, and text content make it easier for students to differentiate the level of information. Based on the validator's input, improvements are needed in the synopsis section, as the sentences are too long. This aligns with Willya et al. (2023), who stated that matching letter types and sizes makes it easier for students to understand reading and obtain meaningful information.

The third indicator is a combination of typeface and letter variation accuracy (bold, italic, capital), consisting of two sub-indicators. The sub-indicator of compatibility of typeface combinations obtained a validation value of 0.93 with valid categories due to the use of easy-to-read typefaces. The correct sub-indicator of letter variation obtained a validation value of 0.87 with valid categories because the use of bold letters for the assertion of important terms and capital letters for the title has been adjusted so as not to interfere with the appearance of the e-comic. This aligns with Willya et al. (2023), who stated that the beauty of learning media, including aesthetics, size harmony, and color combinations, can increase students' interest. The fourth indicator, namely the compatibility of color combinations in e-comics, consists of one sub-indicator, which yields an Aiken's V validation average of 0.87 with valid categories. This value was obtained by matching text colors, backgrounds, and illustrations so that the e-comic appearance is more attractive and can differentiate parts of the story and information without disturbing the readability of the text. This is supported by Aini et al. (2025), who state that the application of appropriate visual media can increase the meaning and attractiveness of learning.

The fifth indicator, namely the harmonized distance between text and illustrations in e-comics, is translated into a single sub-indicator. This sub-indicator had an average Aiken's V value of 0.87, indicating a valid category. The value indicates that the placement of the text does not mask the illustrations, that the spacing of the text and the images is appropriate, and that this makes it easier for the reader to understand the interrelationship between the two. The precise distance between text and illustration facilitates more effective information absorption without making the relationship between text and images difficult to understand (Willya et al., 2023).

c. Language eligibility aspects

The language eligibility aspect of the validation process must comply with Indonesian language rules, be easy to read, and be communicative (Telaumbanua & Zega, 2023). This aspect includes four indicators: using language that is simple and easy to understand, not convoluted, and able to convey information clearly, in accordance with students' abilities; using sentence structures based on PUEBI; and using terms in accordance with the KBBI. Overall, the language eligibility aspect obtained an Aiken's V average score of 0.92 with valid categories.

The first indicator is the use of simple, easy-to-understand language in e-comics, which yielded an average validation value of 0.96 across valid categories. This indicator consists of three sub-indicators. The simple, easy-to-understand sub-indicators of language use each received an Aiken's V score of 0.93 because they used general vocabulary and were not very specific, making them easier for students to

understand. The sub-indicator of language conformity with students' abilities obtained an Aiken's V score of 1.00 because the material was prepared to match students' cognitive level, and appropriate terms were used. However, based on validator input, improvements are needed to better align the language with the rules of scientific writing. This aligns with Juneli et al. (2022), who state that clarity and language effectiveness determine the success of message delivery.

The second indicator is the use of language in e-comics, which is not complicated and conveys information clearly, yielding an average Aiken's V value of 0.93, with a valid category. This indicator is translated into two sub-indicators. The first sub-indicator, the use of non-convoluted language, obtained an Aiken's V value of 0.87, indicating that sentence structure is placed directly at the core of the discussion without repetition or unnecessary word use, thereby facilitating the reader's understanding (Aini et al., 2025). The second sub-indicator, language ability to convey information, obtained an Aiken's V value of 1.00 with valid categories, because the use of clear language allows messages to be understood well without causing confusion. This aligns with communication theory, which emphasizes clarity, accuracy, and relevance in conveying messages (Ginting & Usiono, 2024).

The third indicator is language with student abilities and the use of sentence structure, as defined in the General Guidelines for Indonesian Spelling (PUEBI), consisting of one sub-indicator. The subindicator for using sentence structure according to PUEBI obtained an average validation value (Aiken's V) of 0.87, with valid categories, because the language is easy to understand, and spelling, punctuation, and writing follow PUEBI rules. This aligns with Willya et al. (2023), who stated that using language in line with PUEBI makes it easier to convey messages clearly. The fourth indicator, namely the conformity of terms with the Big Indonesian Dictionary (KBBI), consists of one sub-indicator, yielding an Aiken's V validation average of 0.87 and a valid category. Value: This was achieved by ensuring that scientific terms in e-comics, such as biotechnology, fermentation, and tissue culture, referred to the official KBBI definitions, thereby avoiding misunderstandings. This is supported by Ginting and Usiono (2024), who state that inappropriate use of language can hinder communication.

2. Student Response to E-Comic On Biotechnology Materials

According to Fitriani et al. (2023), student response refers to students' responses to the media being developed. According to Sulisty (2020), a response is an answer given by respondents through a questionnaire containing certain questions to obtain opinions and information. After validating the process, the next stage involves a limited trial with 20 students using a questionnaire on their responses to the media e-comic. This response questionnaire is used to assess how far the student's response or response to the media is e-comic regarding the biotechnology material used in the previous learning process. The results of the average analysis of the student response are presented in Table 4.

Table 4
Results of Student Response Analysis

	Indicator	Score (%)	Score Category
Affective	Motivation	75.83	Ok
	Withdrawal	78.75	Ok
Cognitive	Clarity of instructions for use e-comic	79.17	Ok
	Display suitability	80.63	Ok
	Understanding of material content	78.75	Ok
Conative	Behavior	77.50	Ok
Average		78.63	Ok

a. Affective Aspects

According to Sulisty (2020), the affective aspect is a part of attitude that includes the feelings or emotions a person has toward an object, which often serve as the basis for good or bad judgments about that object. The affective aspect consists of two indicators. The first indicator, namely motivation, obtained an average score of 75.83%, which shows that e-comic this biotechnology material, can increase students' enthusiasm for learning because the e-comic media presents the material in an interesting way, easily understood by the students, combining text and images, so that the students feel more interested in studying the material that the students may initially find difficult. As per Saqujuddin & Saputra (2025), the use of technology-based learning media, such as e-comics, is expected to increase students' interest in learning and provide a fun and effective learning experience. The second indicator,

namely attractiveness, obtained an average score of 78.75%, indicating that the design and presentation of the material are deep e-comics that can attract students' attention. According to Juneli et al. (2022), the use of digital comic media can foster student interest and create an effective learning environment.

b. Cognitive Aspects

According to Sulistyo (2020), cognitive aspects are parts that contain a person's beliefs and thoughts regarding an object of attitude, including facts, knowledge, and beliefs about that object. The cognitive aspect consists of three indicators. The first indicator, clarity of instructions for use, for the e-comic obtained an average score of 79.17%. This value is obtained because the language is simple and easy to understand, sentences are clear, and commonly used terms make it easier for students to use e-comics. According to Ranting & Wibawa (2022), the advantages of media e-comics include attracting students' attention during reading and being easy to understand, which helps them be remembered longer. The material is light, easily accessible at any time via electronic media, and very easy to use. The second indicator is the suitability of the display on e-comic. This biotechnological material obtained an average value of 80.63%. According to Alricoh et al. (2021), media e-comics have a simple presentation, employ story sequence elements that convey large messages concisely and are easily digested, and use dialogical verbal language. The third indicator is understanding the content of the material; e-comic biotechnological materials obtained an average value of 78.75%. This value is obtained because understanding the material's content in line with the student's cognitive level and its difficulty aligns with learning indicators. According to Aini et al. (2025), media e-comics are effective at conveying information visually and narratively, thereby creating a learning experience that is more engaging and easier for students to understand.

c. Conative Aspects

According to Sulistyo (2020), conative or behavioral aspects include an individual's readiness to respond and the tendency to act towards an object. The conative aspect, which consists of a single indicator, is behavior, as evidenced by an average score of 77.50% in the "Good" category. This value is obtained because the e-comic developed has an attractive, interactive design that encourages students to be more actively involved in the learning process. According to Zakiyah (2022), media e-comics are not only visually appealing but also encourage active engagement and critical thinking among students.

CONCLUSION

Media e-comic, which focus on validated biotechnology material that is suitable for use as an alternative medium in the learning process. Based on the validation results, the five validators produce values within valid categories. In addition, the reliability test results, which showed the values fell within the category, were very good. Apart from that, the assessment of student responses yielded good scores. These results show that the media e-comic biotechnology material receives a positive response from students and is effectively used in the learning process. Through this research, biology teachers are expected to be able to leverage e-comics. This biotechnology material serves as an alternative medium for learning and for developing advanced editions that incorporate other subject matter to enrich students' learning experiences.

REFERENCES

- Aiken L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, 45, 131-142. <https://doi.org/10.1177/001316448545101>
- Alricoh, E. B., Paramita, S., & Pandrianto, N. (2021). Strategi Pengarang Ghosty's Menghadapi Persaingan Komik Digital (Studi pada Komik Ghosty's). *Prologia*, 2598-0777. <https://doi.org/10.24912/pr.v5i1.8078>
- Aini, S. N., Princess, T. A., Setyawan, N. R., & Nugraheni, L. (2025). Analisis Penguatan Pendidikan Karakter dan Peningkatan Literasi Siswa Sekolah Dasar Berbasis Dongeng "Rahasia Hutan Belantara" Melalui Pembelajaran Komik Digital. *Learning Dynamics: Journal of Education and language*, 2(3), 196-208. <https://doi.org/10.62383/dilan.v2i3.1945>
- Amir, T. 2015. Designing Questionnaires: Concepts and guides for attitude, personality, and behavior research. Jakarta: Prenadamedia Group.
- Arum, A. E., Khumaedi, M., & Susilaningsih, E. (2022). Pengembangan Instrumen Penilaian Domain Afektif (Sikap) Kepercayaan Diri pada Siswa. *Basicedu Journal*, 6(3), 5467-5474.

<https://doi.org/10.31004/basicedu.v6i3.3203>

- Aryandi, J., & Onsardi, O. (2020). The Influence of Service Quality and Location on Consumer Purchase Decisions at Cafe Wareg Bengkulu. *Journal of Human and Business Capital Management (Jmmib)*, 1(1), 117-127. <https://doi.org/10.61567/jmmib.v1i1.12>
- Doyan, A., Ayub, S., & Harjono, A. (2024). Effectiveness of Thermodynamics Textbooks Assisted by Heyzine Flipbook to Improve Students' Generic Science, Critical Thinking and Conceptual Understanding. *Science Education Research Journal*, 10(10), 7839-7844. <https://doi.org/10.29303/jppipa.v10i10.9091>
- Duda, H. J. ., Wahyuni, F. R. E., Setyawan, A. E., Supiandi, M. I., & Bustami, Y. (2022). Development of project based biotechnology teaching books. *Biosfer: Jurnal Pendidikan Biologi*, 15(2), 178-191. <https://doi.org/10.21009/biosferjpb.18003>
- Fahira, A. P., & Puspitawati, R. P. (2025). Analisis Trend Bibliometrik STEM dalam Pembelajaran Biologi untuk Melatihkan Kemampuan Berpikir Kritis. *Periodical Scientific Biology Education (BioEdu)*, 14(1), 260-269. <https://doi.org/10.26740/bioedu.v14n1.p260-269>
- Firmadani, F. (2020). Media pembelajaran berbasis teknologi sebagai inovasi pembelajaran era revolusi industri 4.0. *KoPeN: National education conference*, 2(1), 93-97. https://ejurnal.mercubuana-yogya.ac.id/index.php/Prosiding_KoPeN/article/view/1084
- Fitriani, D. E. N., Amelia, E., & Marianingsih, P. (2017). Penyusunan modul pembelajaran berbasis sains teknologi dan masyarakat (stm) pada konsep bioteknologi (sebagai bahan ajar siswa sma kelas xii). *Biosfer: Jurnal Pendidikan Biologi*, 10(2), 60-72. <https://doi.org/10.21009/biosferjpb.10-2.8>
- Fitriani, F., Rahayu, H. M., Setiadi, A. E., & Susanti, H. (2023). Validasi dan Respon Siswa terhadap Komik Digital Bioteknologi Berbasis Potensi Lokal Kalimantan Barat. *Susunan Artikel Pendidikan*, 8(1), 1-8. <http://dx.doi.org/10.30998/sap.v8i1.13682>
- Ginting, R. R. B., & Usiono, U. (2024). Systematic Literature Review (SLR): Good and Correct Use of Indonesian in Daily Life-Days. *Journal of Science Student Research*, 2(6), 494-505. <https://doi.org/10.61722/jssr.v2i6.3007>
- Hadianty, H., Rochman, C., & Rahmawati, R. (2025). Evaluasi Hasil Belajar Siswa Pada Materi Bioteknologi dalam Meningkatkan Kemampuan Literasi Sains. *BIODIK*, 11(1), 180-188. <https://doi.org/10.22437/biodik.v11i1.41244>
- Hafidzah, H., Subayani, N. W., & Alfiansyah, I. (2021). Pengembangan Modul Ajar Kepoh (Komik Edukasi Profesor Hana) Materi Perubahan Wujud Benda Kelas Iii Sekolah Dasar. *JTIEE (Journal of Teaching in Elementary Education)*, 5(1), 1-16. <https://doi.org/10.30587/jtiee.v5i1.2783>
- Handayani, T. (2021). Development of STEM-Based Digital Comics Media to Improve Science Literacy of Primary School Students. *Journal of Basic Education Didactics*, 5(3), 737-756. <https://doi.org/10.26811/didaktika.v5i3.343>
- Juneli, J. A., Sujana, A., & Julia, J. (2022). Development of Digital Comic Learning Media in Mastering the Concepts of Class V Elementary School Students. *Primary: Journal of Primary School Teacher Education*, 11(4), 1093. <http://dx.doi.org/10.33578/jpkip.v11i4.9070>
- Kartini, K. S., & Sons, I. N. T. A. (2020). Respon siswa terhadap pengembangan media pembelajaran interaktif berbasis android. *Jurnal pendidikan kimia indonesia*, 4(1), 12-19. <https://doi.org/10.23887/jpk.v4i1.24981>
- Khazalina, T. (2020). Saccharomyces cerevisiae in the Manufacture of Conventional Biotechnology-Based Halal Products and Genetic Engineering. *Journal of Halal Product and Research*, 3(2), 88-94. <https://doi.org/10.20473/jhpr.vol.3-issue.2.88-94>
- Koo, T. K., & Li, M. Y. (2016). A Guideline Of Selecting And Reporting Intraclass Correlation Coefficients For Reliability Research. *Journal of chiropractic medicine*, 15(2), 155-163. <https://doi.org/10.1016/j.jcm.2016.02.012>
- Lestiani, W., Thomas, O., Centauri, B., & Toendan, K. (2021). pengembangan media komik digital "bahaya virus" pada mata pelajaran biologi. *Jurnal Teknologi Pendidikan (JTP)*, 14 (2), 125-131. <https://doi.org/10.24114/jtp.v14i2.23282>
- Marcellina, R. J., Karyadi, B., Parlindungan, D., Uliyandari, M., & Sutarno, M. (2023). Pengembangan E-Booklet Lemea Lebong sebagai Media Pembelajaran Materi Bioteknologi untuk Siswa SMP. *Bioedusiana*, 6(1), 110-119. <https://doi.org/10.31539/bioedusains.v6i1.5923>

- Maharani, N. A. A., & Fernandes, R. (2022). The urgency of e-comic media in sociology learning in high school. *Sikola Journal: Journal of Education and Learning Studies*, 4(1), 47-54. <https://doi.org/10.24036/nara.v1i3.198>
- Nawali, J., Savika, H. I., Mufidah, I. K., & Susilawati, S. (2024). Pengembangan media pembelajaran di mi dan sd. *Cahaya*, 2(1), 37-49. <https://doi.org/10.70115/cahaya.v2i1.133>
- Paramita, R., Panjaitan, R. G. P., & Ariyati, E. (2018). Pengembangan booklet hasil inventarisasi tumbuhan obat sebagai media pembelajaran pada materi manfaat keanekaragaman hayati. *Jurnal IPA dan Pembelajaran IPA*, 2(2), 83-88. <https://doi.org/10.24815/jipi.v2i2.12389>
- Pinatih, S. A. C., & Sons, D. K. N. S. (2021). Development of digital comic media based on a scientific approach to science content. *Journal of Educational Research and Development*, 5(1), 115-121. <https://doi.org/10.23887/jppp.v5i1.32279>
- Qammaddin, S. S. (2021). Dick Dan Carey Model Computer Network Learning Design Based on Information Technology Infrastructure Library (ITIL) Service Management. *Instructional*, 2(2), 76-81. <https://doi.org/10.24853/instruksional.2.2.76-81>
- Twig, N. W., & Wibawa, I. M. C. (2022). Digital comic media on the topic of energy sources. *Edutech Undiksha Journal*, 10(2), 262-270. <https://doi.org/10.23887/jeu.v10i2.47743>
- Sari, A. W., Djulia, E., & Edi, S. (2025). Developing The Biology Digital Comics Usa The Media For Learning Of Human Circulatory Systems. *JOURNAL OF SCIENCE AND SOCIAL RESEARCH*, 8(1), 415-420. <https://doi.org/10.54314/jssr.v8i1.2732>
- Saqjuddin, S., & Saputra, E. E. (2025). Pengembangan Media Komik Digital untuk Meningkatkan Minat Belajar IPS pada Siswa Sekolah Dasar. *Jurnal Pendidikan Multidisiplin*, 1(2), 65-74. <https://doi.org/10.54297/jpmd.v1i2.1210>
- Shintawati, E. (2023). Technology-Based Learning Media as Learning Innovation at SDN 262 Panyileukan. *PGSD Uniga Journal*, 148-157. <https://doi.org/10.52434/jpgsd.v2i1.2530>
- Siregar, S. U., Nazliah, R., Hasibuan, R., Julyanti, E., & Siregar, M. (2021). Manajemen peningkatan kualitas pembelajaran matematika pada sma labuhanbatu. *Education and Development Journal*, 9(2), 285-290. <https://journal.ipts.ac.id/index.php/ED/article/view/2569>
- Sugiyono. (2021). *Metode penelitian kuantitatif, kualitatif dan Penelitian dan pengembangan*. Bandung: Alfabet.
- Sulistyo, B. (2020). Strategi Komunikasi dalam membentuk Budaya Keselamatan kerja melalui Implementasi Observasi PEKA (Pengamatan Keselamatan Kerja) di PT. X. *Jurnal Kajian Ilmiah*, 20(1), 1-12. <https://doi.org/10.31599/jki.v20i1.66>
- Sulistiyowati, A., & Roshayanti, F. (2022). Profil Kemandirian dan Kreativitas Siswa SMA Sedes Sapientiae Semarang pada Pembelajaran Konsep Bioteknologi. *Jurnal Kualita Pendidikan*, 3(1), 10-15. <https://doi.org/10.51651/jkp.v3i1.134>
- Telaumbanua, P. C., & Zega, I. (2023). Pengembangan media pembelajaran e-komik pada materi menganalisis teks negosiasi kelas X SMA Negeri 1 Gunungsitoli. *Primary Education Journals (Elementary School Journal)*, 3(3), 196-204. <https://doi.org/10.33379/primed.v3i2.3061>
- Wahyuniasti, I., Oprasmani, E., & Putri, A. N. (2022). Validity and Practicality of Development of Science Literacy-Based E-Modules in Class IX Biotechnology Materials. *Student Online Journal (SOJ) UMRAH-Teacher Training and Education*, 3(1), 503-510. <https://soj.umrah.ac.id/index.php/SOJFKIP/issue/view/37>
- Willya, A. R., Luthfiyyah, A., Simbolon, P. C., & Marini, A. (2023). The role of digital comic learning media to foster students' interest in reading in elementary schools. *Journal of Basic Education and Social Humanities*, 2(3), 449-454. <https://doi.org/10.53625/jpdsh.v2i3.4518>
- Yulianah, F., Siswandari, S., & Sudiyanto, S. (2017). Pengembangan media komik digital akuntansi pada materi menyusun laporan rekonsiliasi bank untuk siswa smk. *Jurnal Pendidikan Dan Kebudayaan*, 2(2), 239-250. <https://doi.org/10.24832/jpnk.v2i2.588>
- Yurdugül, H., & Cetin, N. M. (2015). Investigation of the relationship between learning process and learning outcomes in e-learning environments. *Eurasian Journal of Educational Research*, 15(59), 57-74. <https://doi.org/10.14689/ejer.2015.59.4>
- Zakiah, Z., Arisandi, M., Oktora, S. D., Hidayat, A., Karlimah, K., & Saputra, E. R. (2022). Pengembangan Buku Teks Bahasa Indonesia Berbasis Media Komik Digital Bermuatan Keterampilan Berpikir Kritis. *Basicedu Journal*, 6(5), 8431-8440. <https://doi.org/10.31004/basicedu.v6i5.3869>