

Microsite-Assisted Interactive E-Learning: Development of Biotechnology Topic Learning Media

¹ Inriani, ^{2*} Fajar Adinugraha, ³ Jendri Mamangkey

^{1,2} Biology Education Study Program, FKIP-Indonesian Christian University, Jakarta, Indonesia

³ Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Makassar, Indonesia

Abstract

Biotechnology learning at the junior high school level still faces obstacles in the form of abstract concepts, limited learning media, and low student involvement in the learning process. This condition shows that there is a gap between the demands of meaningful learning and the media used in the classroom. This research produces an interactive e-learning media based on microsites on biotechnology materials. The research method uses a Research and Development (R&D) approach with the stages of needs analysis, design, development, and test student perception. The feasibility of the media was assessed by experts, while student perceptions were collected through questionnaires. The results of the study showed that the biotechnology microsite has a very high feasibility rate with a percentage of 91.94%. In addition, the results of student perception showed an average score of 81.97% in the very good category, which reflected the positive response of students to the appearance, ease of use, completeness of components, and the ability of the media to increase learning motivation. It integrates learning videos, interactive materials, worksheets, online quizzes, and discussion forums in a single platform. Thus, the use of microsites as e-learning media reflects the effective integration of digital technology to support biotechnology learning innovations that are adaptive to educational developments in the digital era.

Keywords: *microsite, microsite-based learning, interactive e-learning, biotechnology, learning media development*

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*Corresponding Author: fadinugraha0608@gmail.com; fajar.adinugraha@uki.ac.id ^{2*}

Introduction

Learning is the process of changing student behavior as a result of interaction between students and the learning environment, both with teachers, peers, and the community. The learning process will not take place optimally without good cooperation between teachers and students ([Adinugraha, et al., 2025](#)). Therefore, teachers are required to make various efforts, one of which is to make learning media with technology that students are able to receive and understand the material optimally ([Dewi & Adinugraha, 2025](#); [Noza et al., 2024](#)). The success of learning is greatly influenced by the selection and development of appropriate and contextual media ([Aruan et al., 2025](#)).

One of the subjects that requires the creativity of teachers and students is Natural Sciences (IPA), especially Biology. Biology is a subject that studies topics about morphology, anatomy, and physiology, biodiversity, ecosystems, and the environment ([Adinugraha et al., 2021](#); [Urry et al., 2011](#)). Biology has a branch of biotechnology that focuses on the use of living things and their derivative products in producing goods and services for humans ([Adrianto et al., 2021](#)). Biotechnology is a science that studies living things, both microorganisms and macroorganisms, the development, utilization and relationship of these fields of science to other sciences ([Wahyuni et al., 2024](#)).

In the Merdeka Curriculum, the learning outcomes of biotechnology materials emphasize mastery of concepts, scientific thinking skills, and the ability to relate science to real-life contexts ([Kemdikbudristek, 2022](#)). Biotechnology material is directed so that students are able to understand the principles of biotechnology and its application in human life, including in supporting food security and

environmental sustainability ([Adrianto et al., 2021](#)). Thus, biotechnology learning in the Merdeka Curriculum not only emphasizes mastery of concepts, but is also contextual, applicative, and oriented towards the development of Pancasila Student profiles, so that students are able to relate the concept of biotechnology to problems and needs of daily life.

However, based on facts and phenomena in the field, biotechnology materials are still considered difficult to understand by students. Secondary data obtained through interviews show that biotechnology is a material that requires critical and creative thinking skills, while learning facilities and infrastructure in schools are still limited, so they become an inhibiting factor in learning (Ramadhani, 2020). Biotechnology material will be difficult for students to understand if they are still unfamiliar with the basic principles ([Mardatillah & Fuadiyah, 2024](#); [Mursali et al., 2024](#)). This fact is reinforced by the results of interviews with teachers at SMP Darul Arqom East Jakarta which shows that the average score of students in biotechnology materials is still much below the set minimum score. In fact, it is hoped that students will be able to understand biotechnology material thoroughly, considering that this material has an important role in equipping students with an understanding of the definition, role, and examples of the application of biotechnology in daily life ([Nugraini & Amelia, 2023](#); [Wahyuni et al., 2024](#)). The gap between the demands of the curriculum and the reality of student understanding shows that there is a phenomenon gap in biotechnology learning.

Various previous studies have shown that the use of technology in learning can be a solution to increase students' understanding and motivation to learn. Several forms of digital media that have been developed include electronic comics that are able to support students' enthusiasm for learning ([Aruan et al., 2025](#)), e-modules that contribute to increasing learning motivation ([Asyhari & Rahmawati, 2021](#)), as well as traditional food context-based e-handouts used in learning ([Handani et al., 2025](#)). However, most of the research still focuses on the development of digital media separately and has not optimized the use of microsite-based media that is able to integrate various electronic elements, such as text, images, video, animation, and audio, in an integrated and interactive manner. In addition, research that specifically examines the development of microsite media on biotechnology materials is still very limited, so further studies are needed to fill this gap.

The microsite is equipped with visual, text, and multimedia components that are expected to increase students' interest and understanding of learning materials, including biotechnology. Microsites can be equipped with interactive features such as videos, electronic worksheets, digital readings, and live worksheets to increase student engagement and motivation ([Situmorang et al., 2025](#)). A microsite is a small website that can be created using S.ID application, which not only serves to shorten links to make them more concise, but also integrates various content on a single page ([Azzahra & Kartiwi, 2024](#)).

Based on the demands of 21st century learning, teachers are required to integrate information technology in the learning process to improve the quality and independence of student learning. The lack of a microsite on the topic of biotechnology is a challenge in itself at SMP Darul Arqom East Jakarta. Therefore, the purpose of this study is to develop interactive e-learning learning media based on microsites on biotechnology materials that are valid and gain positive perceptions for junior high school students. The urgency of this research lies in the effort to provide learning media that is able to bridge the gap between the complexity of biotechnology materials and students' comprehension skills, as well as support more effective, contextual, and technology-based learning.

Method

Research Method

This research uses a Research and Development (R&D) approach which refers to the stages of development according to [Sugiyono \(2019\)](#). These development stages include the identification of potentials and problems as the basis for product development needs, data collection sourced from

theoretical studies and field findings, and product design in accordance with the data that has been obtained. Furthermore, the designed product is assessed by experts to determine its feasibility level, then revised based on the input from the assessment results. The next stage is product testing, both on a limited scale and on a wider scale, followed by product improvements according to the test results. The development process also includes usage tests, final product revisions, and mass production stages. However, in this study, the R&D process was limited only to the perception test stage involving students, so the stage of use and mass production test was not carried out.

Research Location and Time

This research was carried out at SMP Darul Arqom Prumpung which is located at Jl. Bekasi IV, RT 1/RW 8, North Cipinang Besar Village, Jatinegara District, East Jakarta City, DKI Jakarta 17136 (location code: QVHH+99C). The research subjects were 39 students in grade IX of Darul Arqom Junior High School, consisting of 19 students in grade IX A and 20 students in grade IX B. The research was carried out in the period from July to December 2023. The initial observation stage was carried out in July–August 2023 through interviews with science/biology subject teachers and the distribution of student needs questionnaires, while the media assessment stage and filling out student perception questionnaires were carried out from December 2023 to January 2024.

Data Collection

The data collection in this study includes three types, namely microsite-based learning media characteristic data, expert validation data, and student perception data on learning media. Media characteristic data was obtained qualitatively through the description of the form, structure, and features of the microsite developed and its relationship with biotechnology materials. This description includes microsite components, such as introductions, learning objectives, materials, videos, modules, and practice questions. Validation data was obtained through expert assessments using validation sheets to assess the feasibility of microsite-based learning media. The expert validation assessment indicator includes 8 indicators with a total of 25 questions. Student perception data was obtained through a questionnaire given to students after using microsite-based learning media. The student perception indicator includes 12 questions.

Data Analysis

Data analysis in this study was carried out through three approaches according to the type of data obtained. First, data on the characteristics of microsite-based interactive learning media were analyzed qualitatively descriptively by explaining their forms, features, and relationships with biotechnology materials in a narrative manner. Second, the data from the expert assessment was analyzed using descriptive statistics through the calculation of average scores, which were then converted into the feasibility category of interactive learning media based on validity criteria, namely 81–100% (very feasible), 61–80% (feasible), 41–60% (fairly feasible), 21–40% (not feasible), and 0–20% (not feasible) ([Anindya, 2023](#)). Third, student perception data on learning media was analyzed descriptively by calculating the average score of the questionnaire results, then classified into the categories of student responses, namely 81–100% (very good), 61–80% (good), 41–60% (adequate), 21–40% (less), and 0–20% (very poor) ([Kartini & Putra, 2020](#)).

Research Results and Discussion

Characteristics of Microsite with Biotechnology Topic

Analysis of needs and field conditions was carried out as an initial stage in the development of biotechnology-based microsite-based learning media. This activity was carried out through interviews with science subject teachers and direct observation of the learning process at Darul Arqom Junior High School, East Jakarta. The results of the analysis showed that grade IX students were in the age range

of 14–16 years old who were cognitively able to think abstractly, but still had difficulties in understanding biotechnology material. These difficulties are caused by the many new terms, abstract concepts, and limited learning media used in the classroom. These findings suggest that the characteristics of students' cognitive development need to be balanced with the use of appropriate learning media ([Ayu et al., 2024](#)) so that abstract concepts can be understood more concretely ([Rahmadilla & Kholidya, 2025](#)).

The biotechnology learning process is still dominated by lecture methods with media support in the form of worksheet, so it does not provide an interesting and meaningful learning experience for students. In addition, the limited learning facilities and infrastructure as well as the less conducive school environment conditions also affect students' concentration and motivation to learn. Based on these conditions, learning media that is able to present material in a concise, visual, easily accessible, and flexible manner is needed both inside and outside the classroom. This condition is in line with the view that effective learning needs to be supported by media that is able to increase student engagement and learning motivation ([Septiyaningsih et al., 2025](#)). Therefore, learning media is needed which is integrated into a microsite as shown in Figure 1.

The material developed in the microsite focuses on biotechnology which includes the definition, types of biotechnology (conventional and modern), examples, and its application in daily life. The material is arranged in the form of a summary in simple language and equipped with supporting images to make it easier for students to understand the concept. The results of the analysis showed that students were more interested in learning media that did not contain too much text, but presented information visually and in a structured manner. This shows that the presentation of material visually and concisely can help students in understanding complex material ([Tarusu & Wongkar, 2024](#)).

The learning tasks designed in the microsite are focused on conventional biotechnology and modern biotechnology. One of the main forms of assignment is the practical activities of making conventional biotechnology products in the food sector, which aims to relate the concept of biotechnology with students' real experiences in daily life. The learning approach based on real and scientific activities is believed to be able to increase conceptual understanding and student involvement in the learning process ([Adinugraha et al., 2021](#)).

Based on the results of the analysis of needs, materials, and tasks, the objectives of biotechnology learning are formulated in a directed manner. These objectives include students' ability to explain the meaning of biotechnology, distinguish between conventional and modern biotechnology, analyze its application and impact on life, identify the application of conventional biotechnology in the food sector, produce biotechnology products creatively and innovatively, and systematically compile activity reports. The formulation of clear learning objectives is an important basis in designing effective and targeted learning media ([Albina & Pratama, 2025](#)).

The learning media developed is in the form of a biotechnology microsite, which is a small website that functions as a center for the integration of various learning resources and learning activities on one page. The microsite is designed to support online learning by connecting various learning media through interintegrated links, so that students can follow the learning series in a sequential and independent manner. The use of microsites as learning media supports the concept of flexible and centralized digital learning ([Situmorang et al., 2025](#)).

The biotechnology microsite integrates various learning support platforms, including simplebooklet for instructions for use, Canva for presentation of learning objectives, YouTube for learning videos, Heyzine Flipbook for concise materials, Google Drive for student activities and worksheets, Quizizz for evaluations, and WhatsApp Group as a discussion forum. All of these components are united in one microsite to facilitate access and improve learning efficiency. The integration of various digital platforms in one learning medium can increase the attention of students ([Nurdiyanti et al., 2025](#)).

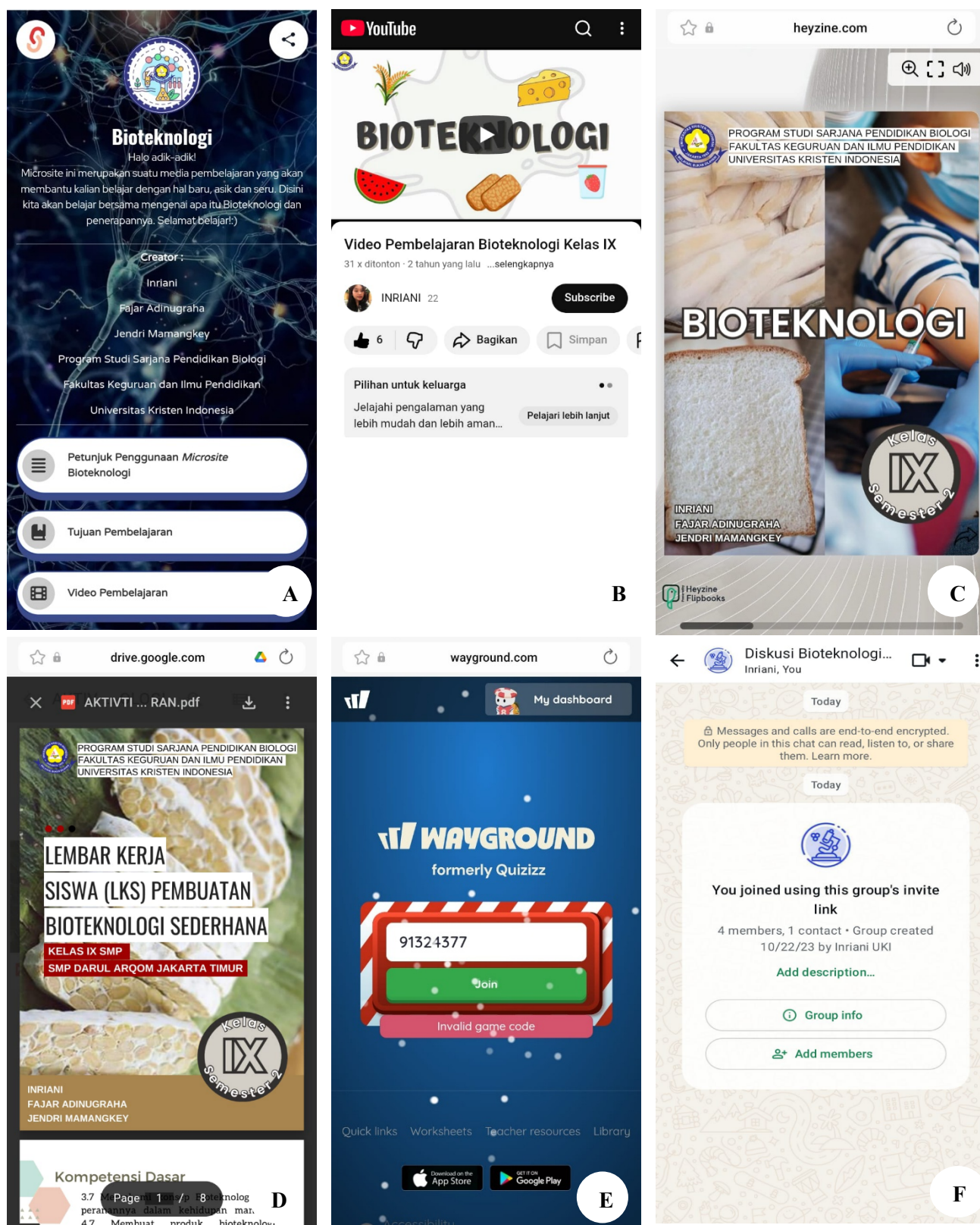


Figure 1. Microsite on biotechnology topics. A. Microsite menu display, B. Learning videos, C. Learning materials in the form of flipbooks, D. Student worksheets, E. Online quizzes, and F. WhatsApp discussion rooms

The biotechnology microsite consists of several main components, namely instructions for use, learning objectives, learning videos, learning materials, project activities, evaluation quizzes, and discussion forums. The instructions for use contain general information about the microsite, media

advantages, and learning steps that students should follow. Learning objectives are designed based on the cognitive domain of Bloom's Taxonomy and are presented visually for easy understanding. The systematic preparation of media components supports structured and outcome-oriented learning (Titin et al., 2023).

Learning videos are used as audio-visual media to explain the concept of biotechnology in a more concrete way, while learning materials serve as summaries to strengthen students' understanding. Learning activities are in the form of projects to make conventional biotechnology products that encourage students to learn actively and collaboratively. Quizzes are used as an evaluation tool to measure student understanding, while discussion forums function as a means of communication and discussion between students and teachers during the learning process. Microsite accessible through <https://s.id/BioteknologiKelasIX>. The use of digital media is in line with the principles of interactive and student-centered learning (Sakti, 2025).

Evaluation of Microsite with Biotechnology Topic

Based on the results of the expert assessment of microsite-based learning media, an overall feasibility percentage of 91.94% was obtained. Referring to the eligibility criteria used, which is 81–100% included in the very feasible category, the biotechnology microsite developed was declared very feasible to be used as a learning medium. These results show that in general, the microsite has met the aspects of suitability of learning objectives, material delivery, material weight, technical quality, composition, integration, as well as clarity and comprehension of the text.

When reviewed based on each indicator, the Learning Objectives indicator obtained a percentage of 90.00% with a very feasible category, which shows that the material in the microsite is in accordance with the competencies and learning objectives and is systematically arranged. The Content Delivery indicator obtained a percentage of 91.11% and is included in the very feasible category, which indicates that the microsite is easy to use, able to motivate students to learn, and encourages curiosity. The Content Weighting indicator obtained the highest percentage, which was 96.67%, with the category of very feasible, which indicates that the material has corresponded to the student's ability level and includes cognitive aspects from C1 to C6.

Furthermore, the Technical Quality indicator obtained a percentage of 93.33% with the very feasible category, which shows that the page appearance, readability of the text, and the attractiveness of the microsite content have met the feasibility standards of learning media. The Composition indicator obtained a percentage of 90.00% and belongs to the very feasible category, which indicates that the flow and arrangement of learning steps in the microsite have been presented systematically and according to the student's ability. The Integrity indicator obtained a percentage of 96.67% with a very decent category, which shows that the integration of colors and content in the microsite has been designed in a harmonious and mutually supportive manner.

Meanwhile, the Text Accuracy indicator obtained a percentage of 86.67% and remained in the very decent category, although some linguistic aspects still required minor refinement. The Text Comprehension indicator obtained a percentage of 91.11% with a very decent category, which shows that the text in the microsite is easy to read, the purpose of delivery is clear, and the terms used are easy for students to understand. Overall, the results of this feasibility test confirm that the biotechnology microsite developed has met the criteria as a learning medium that is very suitable for use in the learning process. The data is presented in Figure 2.

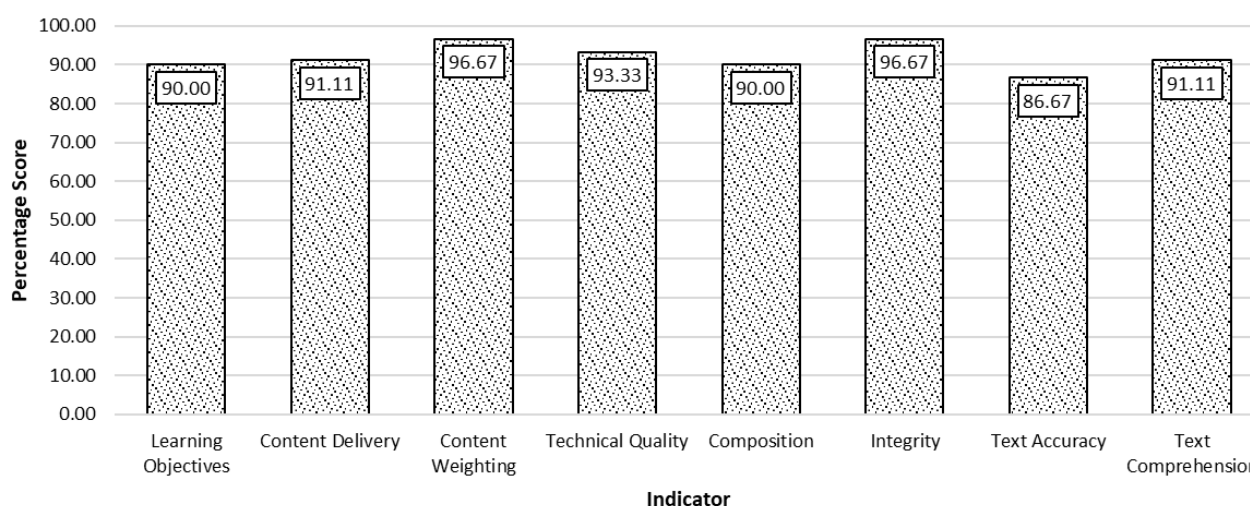


Figure 2. Assessment Biotechnology Microsite by experts per indicator

The results of the feasibility test of biotechnology-based microsite-based learning media which reached an overall percentage of 91.94% showed that the developed media was in the category *Very deserved*. These findings are in line with constructivist theory which emphasizes that learning is more meaningful when students can build their own understanding through interaction with rich and structured learning resources. The microsite allows students to access materials, videos, and exercises independently, thus actively supporting the knowledge construction process ([Azzahra & Kartiwi, 2024](#)), especially in biotechnology materials that are complex and applicative.

High achievement in indicators Content Weighting and integrity show that the preparation of the material has been appropriate to the student's level of cognitive development and includes cognitive aspects from C1 to C6. This is in line with the revised Bloom taxonomy, which emphasizes the importance of developing low- to high-level thinking skills gradually. In addition, the integration of text, visuals, and learning flows in the microsite supports the Cognitive Theory of Multimedia Learning which states that learning will be more effective when information is presented through verbal and visual channels in an integrated manner, thereby reducing the cognitive burden on students ([Mayer, 2024](#)).

The content delivery and technical quality indicators that are also in the category are very feasible showing that the microsite is able to present material clearly, attractively, and easily use. This supports the theory of user-centered learning, where ease of navigation and visual display play an important role in increasing student motivation and learning engagement. Although the text accuracy indicator has a relatively lower percentage than other indicators, the achievement in the text comprehension indicator still shows that students can understand the content of the material well. Thus, this microsite-based learning media is not only technically feasible, but also theoretically relevant in supporting effective, contextual, and student-oriented biotechnology learning.

Students' Perception of the Microsite with Biotechnology Topic

The results of the student perception questionnaire on biotechnology-based microsite-based learning media showed an overall positive response. Most of the items obtained percentages in the categories of excellent (81–100%) and good (61–80%), indicating that the microsite was well received by students as a learning medium. Items related to media display, design neatness, color selection, and completeness of microsite components (introduction, objectives, videos, modules, and practice questions) obtained a high percentage, thus showing that the visual aspects and media structure are able to attract students' attention and support learning comfort. Perception data is shown in Figure 3.

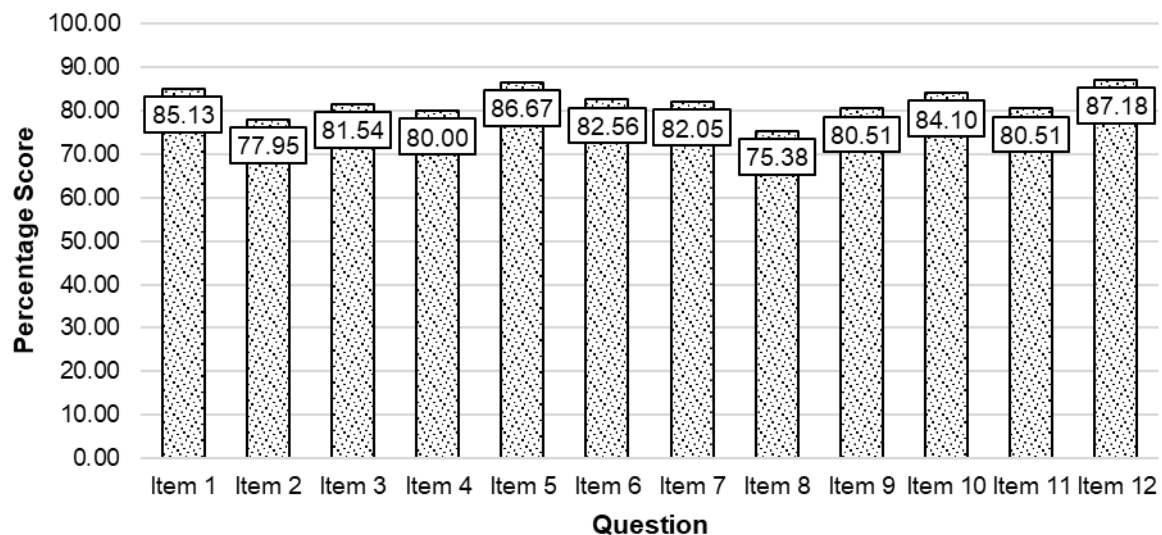


Figure 3. Students' perception of the Biotechnology Microsite

In terms of ease of use and understanding, most items are also in the good to very good category, such as ease of use of media, clarity of instructions, readability of layout and arrangement of letters, and the use of easy-to-understand language. This shows that the microsite is designed with the needs and characteristics of students in mind, so that it is not difficult for students to access or understand the biotechnology material presented. In addition, the item regarding the completeness of the media component obtained the excellent category, which indicates that the integration of various learning elements in one microsite helps students learn more in a more directed and independent manner.

Meanwhile, several items such as ease of understanding the material and increasing learning motivation are in the good category, which indicates that although the microsite has been able to support the learning process positively, there is still room for further development so that the media is more optimal in facilitating understanding of concepts and increasing student learning motivation. Overall, the results of this student's perception confirm that biotechnology microsite learning media is feasible to use and has great potential to create an interesting, fun, and meaningful learning experience.

The results of student perception, which showed the good to very good category in almost all indicators, indicated that biotechnology-based learning media was able to support the learning process effectively. The high response of students to the media display, neatness of the design, color selection, and completeness of microsite components is in line with the Cognitive Theory of Multimedia Learning which states that learning will be more optimal when information is presented through a combination of integrated visual and verbal elements (Mayer, 2024). Presentation of material through text, images, and videos to help students manage information more efficiently (Aruan et al., 2025) thus making it easier to understand abstract biotechnology concepts.

In addition, the categories of ease of use, clarity of instructions, and readability of layout and language indicate that the microsite has been designed in accordance with the principles of student-centered learning. Easy-to-use media allows students to learn independently without experiencing technical barriers, so that students' attention can be focused on understanding the material. It also supports constructivist theory, which emphasizes that learning is more meaningful when students actively build their own knowledge through interaction with available learning resources (Sjøberg, 2010; Vygotsky, 1978).

Students' positive perceptions of indicators of increased learning motivation and more enjoyable learning activities show that the use of microsities plays a role in increasing student learning engagement. These findings are in line with the theory of learning motivation which states that learning

media that are engaging, interactive, and relevant to students' needs can increase interest and motivation to learn (Pranyoto, 2023). Motivation is the dominant internal factor in the learning process, followed by health conditions, learning interests, fitness, and talents (Ponto et al., 2022). The results of student perception reinforce that biotechnology microsities not only function as a means of delivering material, but also as a medium that is able to create a more interesting, contextual, and meaningful learning experience.

This study has several limitations that need to be considered in interpreting the results. First, the research and development process of microsite-based learning media is only carried out up to the stage of testing students' perception, so that it has not been empirically tested the influence of microsite use on improving learning outcomes or students' high-level thinking skills. Second, the research subject is limited to one school and one grade level, so the generalization of the research results is still limited. Third, biotechnology materials are still made in a general nature, such as making tempeh, tape, and other fermentations. In fact, Indonesia is rich in conventional biotechnology.

Based on these limitations, further research is recommended to continue the development stage to test its widespread use and examine the effectiveness of microsite-based learning media on learning outcomes. In addition, it is necessary to develop microsities based on local wisdom, such as making *koro benguk* tempeh (Ratnapuri et al., 2025), bioenzyme (Adinugraha, Sitinjak, et al., 2025), traditional food (Marpaung et al., 2025), and traditional cheeses (Harmiatur et al., 2024). The development of microsite-based learning media that integrates digital technology and local wisdom has the potential to strengthen learning that is contextual, meaningful, and relevant to the social and cultural environment of students in the era of digital education transformation.

Conclusion

E-learning assisted by microsite learning media on biotechnology materials has met the eligibility criteria based on expert assessments. This microsite is designed in an integrated manner by combining the main menu as a navigation center, learning videos, biotechnology materials in the form of flipbooks, student worksheets, online quizzes, and WhatsApp-based discussion rooms, allowing students to flexibly access learning materials, activities, and evaluations in one platform. The results of students' perceptions showed a positive response to the use of microsities, especially in terms of appearance, ease of use, completeness of components, and their ability to increase motivation and learning comfort. Overall, this microsite-based learning media is suitable for use as an alternative to e-learning in biotechnology learning at the junior high school level and reflects the effective use of digital technology to support learning innovations that are adaptive to educational developments in the digital era.

Reference

- Adinugraha, F., Ratnapuri, A., Ponto, A. I., & Novalina, N. (2021). Learning approaches in Biology learning. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 11(1), 25–34. <https://doi.org/10.30998/formatif.v11i1.6529>
- Adinugraha, F., Sitinjak, R., Sunarto, Silalahi, M., Wahyuningtyas, R. S., Murniarti, E., Ratnapuri, A., & Agustianto, W. (2025). Pelatihan bioenzim dan pupuk lacuba untuk mendukung pengetahuan dan persepsi siswa terhadap pertanian berkelanjutan di SMA Negeri 1 Sititio, Kabupaten Samosir. *Cakrawala*, 4(3).
- Adinugraha, F., Zubaidah, S., & Lestari, S. R. (2025). Effectiveness of indigenous knowledge-oriented instructional modules to promote biodiversity literacy. *Pertanika J. Soc. Sci. & Hum*, 33(5), 2073–2094. <https://doi.org/10.47836/pjssh.33.5.12> E-mail
- Adrianto, H., Ulinniam, Purwanti, E. W., Yusal, M. S., Widyastuti, D. A., Sutrisno, E., Tamaela, K. A., Dailami, M., Purbowati, R., Angga, L. O., Hasibuan, A. K. H., Hariri, M. R., Nendissa, D. M., Nendissa, S. J., Noviantari, A., & Chrisnawat, L. (2021). *Bioteknologi*. Widina Bhakti.
- Albina, M., & Pratama, K. B. (2025). Peran tujuan pembelajaran dalam perencanaan pembelajaran:

- Dasar untuk pembelajaran yang efektif. *Harmoni Pendidikan*, 2(2).
- Anindya, A. (2023). Pengembangan Media Pembelajaran Interaktif Berbasis Microsoft Power Point Pada Pembelajaran IPA Kelas V SD. *Journal Education and Technology*, 4, 1–11.
- Aruan, D. N., Adinugraha, F., Ratnapuri, A., & Setiati, N. (2025). Integrating comic into Biology education handout: Enhancing reproductive health learning at SMA 1 Cawang Baru. *Pro-Life*, 12(2022), 51–62.
- Asyhari, A., & Rahmawati, A. (2021). Pengaruh blended learning berbasis elektronik modul pada materi ekosistem terhadap motivasi belajar siswa di MA NU Mazro'atul Huda Karanganyar Demak. *Pro-Life*, 8(3). <https://doi.org/10.33541/pro-life.v8i3.3475>
- Ayu, K., Fransiska, W., Suarni, N. K., & Margunayasa, I. G. (2024). Perkembangan kognitif siswa pada penggunaan media pembelajaran digital ditinjau dari teori Jean Piaget: Kajian literatur sistematis. *Ideguru*, 9(2), 466–471.
- Azzahra, I. S. S., & Kartiwi, Y. M. (2024). Edukasi microsite interaktif s.id dalam lembar kerja peserta didik bermuatan profil pelajar Pancasila untuk meningkatkan minat siswa memproduksi teks biografi. *Transformasi*, 4(2), 3–8.
- Dewi, A. P., & Adinugraha, F. (2025). Bringing ecosystems to the 3d world: Students' characteristics , assessments , and perceptions of Edu Assemblr Media. *Journal of Science Education for Sustainable Development*, 1(1), 14–21.
- Handani, C. R., Silalahi, M., & Wahyuningtyas, R. S. (2025). Development of e-handout based on local wisdom of Betawi traditional food in Junior High School on digestive system materials. *Pro-Life*, 12(2). <https://doi.org/10.33541/pro-life.v12i2.6847>
- Harmiatun, Y., Wahyuningtyas, R. S., & Nadila, N. (2024). Pembuatan keju zea dengan bahan dasar susu jagung dan telur ayam menggunakan buah Ceremai dengan uji organoleptik. *Pro-Life*, 11(2).
- Kartini, K. S., & Putra, I. N. T. A. (2020). Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android. *Jurnal Pendidikan Kimia Indonesia*, 4(1), 12. <https://doi.org/10.23887/jpk.v4i1.24981>
- Kemdikbudristek. (2022). Keputusan Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan Kemdikbudristek nomor 008/H/KR/2022 (008/H/KR/2022). [https://doi.org/10.1290/1543-706x\(2006\)42\[39-ab:p\]2.0.co;2](https://doi.org/10.1290/1543-706x(2006)42[39-ab:p]2.0.co;2)
- Mardatillah, A., & Fuadiyah, S. (2024). Pengembangan E-LKPD berbasis project based learning (PjBl) bernuansa kearifan lokal pada materi bioteknologi Fase E SMA: Meta analisis. *Biogenerasi*, 9(2).
- Marpaung, D. S., Hutabarat, G., Glory, S., Saitauma, J., Simanjuntak, T., Simamora, K. C., Listra, & Adinugraha, F. (2025). Kajian etnobiologi Dekke Na Niarsik (Cyprinus carpio L.) sebagai konten video edukasi pada topik biodiversitas. *Bioconsortium*, 2(1).
- Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review*, 36(1), 1–25. <https://doi.org/10.1007/s10648-023-09842-1>
- Mursali, P. R., Latjompoh, M., Uno, W. D., Nusantara, E., Hasan, A. M., & Renowati, Y. (2024). Pengembangan media pembelajaran e-booklet pada materi bioteknologi berbasis hasil kajian fermentasi durian (tempoyak) di SMA Negeri 3 Gorontalo Utara. 7, 14600–14615.
- Noza, A. P., Wandira, R. A., & Gusmaneli. (2024). Pentingnya metode belajar dalam proses pembelajaran. *Jurnal Kajian Ilmiah Interdisipliner*, 8(4), 158–164.
- Nugraini, A. R., & Amelia, R. N. (2023). Analisis pemahaman konsep materi bioteknologi pada siswa Kelas XII SMA. *Seminar Nasional IPA XIII*, 367–372.
- Nurdiyanti, Anisa, & Ananthakkarasu, V. (2025). Digital literacy of Senior High School Science Students: A Case Study of Technology Use in Daily Academic Life. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 14(2), 173–184. <https://doi.org/10.26740/jpps.v14n2.p173-184>
- Ponto, A. I., Adinugraha, F., & Wahyuningtyas, R. S. (2022). Hubungan antara faktor internal dan hasil belajar Biologi siswa kelas XI MIPA SMA Negeri 37 Jakarta pada masa pandemi Covid-19. *JPDK*, 4, 46–52.
- Pranyoto, Y. H. (2023). Pengaruh penggunaan media pembelajaran terhadap motivasi belajar pendidikan agama katolik pada siswa kelas v SD YPPK Don Boscho Budhi Mulia Merauke. *JUMPA*, XI(1), 1–17.
- Rahmadilla, H., & Kholidya, C. F. (2025). Penggunaan media benda Konkret dalam meningkatkan pemahaman konsep pengurangan pada mata pelajaran Matematika siswa kelas II SDN Punggul I. *Jurnal Mahasiswa Teknologi Pendidikan*, 14(11).

- Ratnapuri, A., Mamangkey, J., Sunarto, S., Silalahi, M., Adinugraha, F., Wahyuningtyas, R. S., Septiani, A., Lomo, J. Y., Sembiring, G. A., Andika, V., Angela, E., & Serafin, A. (2025). Peningkatan keterampilan berbasis produk lokal terfermentasi melalui pembuatan tempe koro benguk bagi siswa SMA. *Reswara*, 6(1).
- Sakti, A. (2025). Meningkatkan pembelajaran melalui teknologi digital. *Juprit*, 2(2).
- Septiyaningsih, D. N., Alkhayya, N., Mardiana, N., & Setiyoko, D. T. (2025). Peran teknologi dalam penggunaan media belajar bagi siswa sekolah dasar. *Journal on Education*, 07(02), 10309–10318.
- Situmorang, R. U., Suciptaningsih, O. A., Pristiani, R., & Malang, U. N. (2025). Microsite s.id sebagai media pembelajaran IPAS tentang sejarah dan budaya Indonesia untuk kelas III Sekolah Dasar. *Jurnal Pendidikan Dasar Perkhasa*, 11(April), 775–788.
- Sjøberg, S. (2010). Constructivism and Learning. In *International Encyclopedia of Education, 8-Volume Set, Third Edition* (pp. 485–490). Elsevier Science. <https://doi.org/10.1016/B978-0-08-044894-7.00467-X>
- Sugiyono. (2019). *Metode penelitian: Kuantitatif, kualitatif, dan R&D*. Alfabeta.
- Tarusu, D., & Wongkar, N. V. (2024). Pemanfaatan media visual untuk meningkatkan hasil belajar siswa kelas V pada mata pelajaran IPAS di SD Inpres Leleko. *Journal on Education*, 07(01), 8387–8395.
- Titin, Yuniarti, A., Shalihah, A. P., Amanda, D., Ramadhini, I. L., Tanjungpura, U., & Artikel, I. (2023). Memahami media untuk efektifitas pembelajaran. *Jutech*, 4(2), 111–123.
- Urry, L. A., Gain, M. L., Minorsky, P. V., Wasserman, S. A., & Reece, J. B. (2011). *Campbell Biology Eleventh Edition*. Pearson.
- Vygotsky, L. (1978). *Mind in society* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (eds.)). Harvard University Press.
- Wahyuni, S., Noviani, N., Sartika, A., Habibie, D., & Handayani, L. (2024). Peran bioteknologi dalam keterkaitan berbagai aspek bidang ilmu pengetahuan serta mewujudkan inovasi dan kreatifitas di kalangan mahasiswa Universitas Harapan Medan. *Jurnal Pengabdian West Science*, 03(01), 73–82.