Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 18 No. 7 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijim.v18i07.48083

PAPER

Development of an Advanced Biology Learning Website in the Fields of Biotechnology, Biochemistry, and Biomedicine with the STEAM Approach

Hendra Susanto[1](✉), Ibrohim[1], Andi Basuki[1], Hidayah Mohd Fadzil[2], Afis Baghiz Syafruddin[1], Ari Gunawan[1]

[1]Universitas Negeri Malang, Malang, Indonesia

[2]Universiti Malaya, Kuala Lumpur, Malaysia

hendrabio@um.ac.id

ABSTRACT

The growing industry has given birth to various innovations, one of which is the emergence of three new branches of knowledge in biology: biotechnology, biochemistry, and biomedicine. However, this branch of science has not been explored in biology education for students. Technology, in the form of online learning platforms, can address current challenges. STEAM-based biology learning can increase student engagement, motivate creative exploration, and stimulate critical thinking. This study aims to develop an advanced biology learning platform and test the feasibility of the learning media. This study follows the analysis, design, development, implementation, and evaluation (ADDIE) model. The results of this study have led to the development of the "Advanced Biology" website, which contains various exciting features for students. This feature includes a homepage display, learning content display, case-based learning, and research project display. This platform provides engaging educational videos and comprehensive learning materials. The case studies on this site offer an overview of problem-solving and the current state of the industry. This media validates learning materials, media, and technology in the ideal category.

KEYWORDS

advanced biology, website, STEAM approach

1 INTRODUCTION

Biology is a field of study that focuses on the role of living organisms and their interactions with the environment [1]. Learning biology requires students to understand the fundamental principles of life, such as evolution, genetics, ecology, and other fields associated with biological science [2]. In recent decades, several technological innovations have shaped and changed the paradigm of the natural sciences, creating new opportunities for research, observation, and further understanding of the living world [3]. Three branches of biology are experiencing significant growth: biotechnology, biomedicine,

Susanto, H., Ibrohim, Basuki, A., Fadzil, H.M., Syafruddin, A.B., Gunawan, A. (2024). Development of an Advanced Biology Learning Website in the Fields of Biotechnology, Biochemistry, and Biomedicine with the STEAM Approach. *International Journal of Interactive Mobile Technologies (iJIM)*, 18(7), pp. 158–172. https://doi.org/10.3991/ijim.v18i07.48083

Article submitted 2023-12-27. Revision uploaded 2024-01-30. Final acceptance 2024-02-12.

and biochemistry [4]. Biotechnology has opened the door to developing various technological products related to human health, agriculture, the environment, energy, and applied science [5]. In addition, biomedicine plays a crucial role in science and technology, offering solutions to global health issues like infectious diseases and cancer [6]. Biochemistry is a science that studies the chemical reactions that occur in living cells or organisms [7]. These three branches of science are beneficial for the advancement of science. The three branches of biology learning are effectively conveyed by teachers during the teaching and learning process at school, which hinders the potential to enhance students' interest in pursuing further studies in advanced biology [8]. In addition, the learning approach at UM Laboratory High School still relies on practical training using a curriculum that requires updating to align with industry demands [9]. Practicum facilities that are less interactive can hinder student understanding [10]. Learning innovation is hindered by the current educational system, which only provides a basic introduction to biological science and fails to delve into advanced biology [11].

STEAM learning stimulates students' creativity, problem-solving, and innovative thinking [12]. STEAM learning allows students to experience a comprehensive and integrated learning process, connecting theory with practical applications in real-world contexts [13]. STEAM methods also create an encouraging environment and support creative exploration, allowing students to engage in collaborative projects [14]. The existing learning alternative is to adopt the STEAM approach, as Fitriyah did in 2021. Namely, STEAM learning significantly affects students' creative thinking skills. The p-value was 0.000, which is less than 0.05, and the F value was 35.551. This result is because STEAM integration can be a learning innovation that generates creative and critical ideas and solutions, making it easier to solve a problem [15]. STEAM can provide an update on the learning system at UM Laboratory High School, which still utilizes a practicum system to enhance student knowledge. Even though practicum successfully enhances observation, interpretation, and research abilities, integrating STEAM can motivate students to enhance their critical thinking skills [16]. However, research in the field of STEAM learning has not significantly advanced the development of innovative teaching methods for advanced biology, the motivation of students to sustain their interest in science, or the preparation of students for the challenges of an increasingly technologically integrated real world [17].

Website-based biology learning combines information technology with biology learning materials and provides easy and interactive access for students [18]. Biology learning websites are designed to provide a dynamic learning experience, facilitating the understanding of biological concepts. Students can access learning content anytime and anywhere, following their own learning pace [19]. Website-based biology learning also facilitates an independent learning approach. Website-based biology learning provides easy access, interactivity, and flexibility in the learning process. Learning websites are a reference source that is continuously updated and broaden students' horizons regarding interesting topics [20]. Several studies have developed website-based learning materials that have had a positive impact on learning.

Advanced biology is essential for high school students to learn because it opens up opportunities for promising career paths in science and technology [21]. The fields of medicine (red biotechnology), renewable energy (white/grey biotechnology), agriculture, and animal husbandry require advanced knowledge of biology to understand more complex scientific concepts [22]. Biology teachers also experience this issue. Teachers experience difficulties teaching biology due to complex concepts and terms, as well as the need for an integrated understanding from the microscopic to the macroscopic scale [9]. Based on these issues, the researchers created an advanced biology learning website focusing on STEAM-based biotechnology, biochemistry, and biomedicine.

The purpose of this study is to develop a learning website for advanced biology education. In addition, this study can provide a wider range of learning resources for UM Laboratory High School, which currently follows the Cambridge curriculum. This Cambridge curriculum combines an emphasis on in-depth mastery of subjects with the development of skills for future study and work to align with the evolution of this field. This study contributes to the development of STEAM-based advanced biology, which involves collaborative projects requiring teamwork to address biological challenges. Students are asked to design bioengineering projects, create learning alternatives inspired by physical principles, or produce multimedia presentations showcasing experimental findings. This study serves as the foundation for endorsing UM Laboratory High School as a research-based institution that follows the Cambridge curriculum.

2 METHOD

In 1996, Dick and Carey developed the analysis, design, development, implementation, and evaluation (ADDIE) model for designing learning systems. This study utilizes a systematic ADDIE approach to develop learning media. This method includes five interrelated and continuous stages for designing and implementing effective learning media [23]. The subsections provide a description of the methods used by the researchers.

2.1 Analysis

The analysis stage in developing learning media is a critical foundation for understanding the needs and characteristics of the audience and the learning context that the media will accommodate. At this stage, media developers focus on gaining an in-depth understanding of several factors that are essential for designing and implementing learning media [24]. The analysis begins by investigating the profile of the audience or students who will use the media. The analysis stages in developing learning media provide a strong foundation for the subsequent stages in the ADDIE method. Researchers analyzed students' understanding of concepts in advanced biology learning [25].

2.2 Design

The second step is to design advanced biology learning materials and media related to materials and their design. Advanced biology education employs a STEAM-based approach. Advanced biology learning tools include websites, observation sheets, and assessment sheets [26].

2.3 Development

The development stage in learning media involves a creative and technical process where the concepts identified in the analysis stage are transformed into a format that students can access and utilize. The development stage involves implementing the design into a tangible form of learning media. This development can include content creation, visual design, and the development of interactive functionality. This stage transforms the design into a final product that can help achieve

learning objectives. This process includes the planning, production, and testing of learning media [27].

2.4 Implementation

The stages of implementing learning media for students refer to the phase when the developed learning media is introduced and used in the learning environment. It involves activities to ensure that learners can access, understand, and make the best possible use of media. Learning materials should be readily available to students through digital platforms, hardware, or physical copies, in accordance with the requirements and regulations of the school or educational institution. Effective implementation enables students to engage in more active and comprehensive learning by utilizing media resources to support the achievement of established learning objectives [27].

2.5 Evaluation

The evaluation stage of using learning media for students is a critical phase that aims to assess the extent to which the learning media has succeeded in achieving the learning objectives that have been set. This evaluation brings essential benefits in understanding the effectiveness of the press, correcting weaknesses that may arise, and ensuring that the use of the media positively impacts the learning process. Evaluation involves measuring students' achievements or accomplishments. This includes improving the understanding of concepts, developing skills, or achieving specific learning objectives. This achievement data collection helps measure the real impact of learning media on student progress [27].

3 RESULTS AND DISCUSSION

3.1 Preliminary studies

Literature studies and field studies are limited in the preliminary stages. Searching for references related to advanced biology learning (biotechnology, biochemistry, and biomedicine) can assist students studying applied science. Students also assist in implementing advanced biology learning patterns at Malang State University Laboratory High School. The field observation process explored the use of STEAM-based learning materials and media in schools. Students and teachers use the existing empirical studies to provide an overview of products and implement learning.

The analysis revealed that several schools had incorporated biotechnology and biology subjects into their curricula. However, they faced limitations due to the high cost of laboratory equipment. Hence, the material provision could have been more optimal [28]. In addition, the current learning approach does not involve a learning management system and has not integrated research-oriented STEAM-based learning. Therefore, the government's implementation of an independent curriculum requires innovative products that will help students enhance their knowledge, but coordination with driving schools is necessary. Advanced biology learning innovations based on STEAM (biotech, biochemistry, and biomedicine) virtual laboratories support the implementation of an independent curriculum. Malang State University Laboratory High School will implement innovative advanced biology learning media.

3.2 Advanced biology concepts

The innovation offered is a system integrated into an advanced biology learning development system (biotech, biochemistry, and biomedicine) based on STEAM virtual laboratory learning. This learning platform consists of various features. Responsive design in cloud-based learning and data security development is crucial for future advancements. Early learning will feature STEAM-based activities focused on identifying herbal plants in the fields of biotechnology, biomedicine, and biochemistry. This learning website provides a variety of services. The website features five essential components: a learning management system, case studies, virtual laboratories, learning cards, and sustainable project planning. The case studies on the website provide an overview of problem-solving and current industrial conditions. Learning management system services provide educational content to enhance students' cognitive abilities. The following is an explanation of concepts related to advanced biology, including biotechnology, biochemistry, and biomedicine.

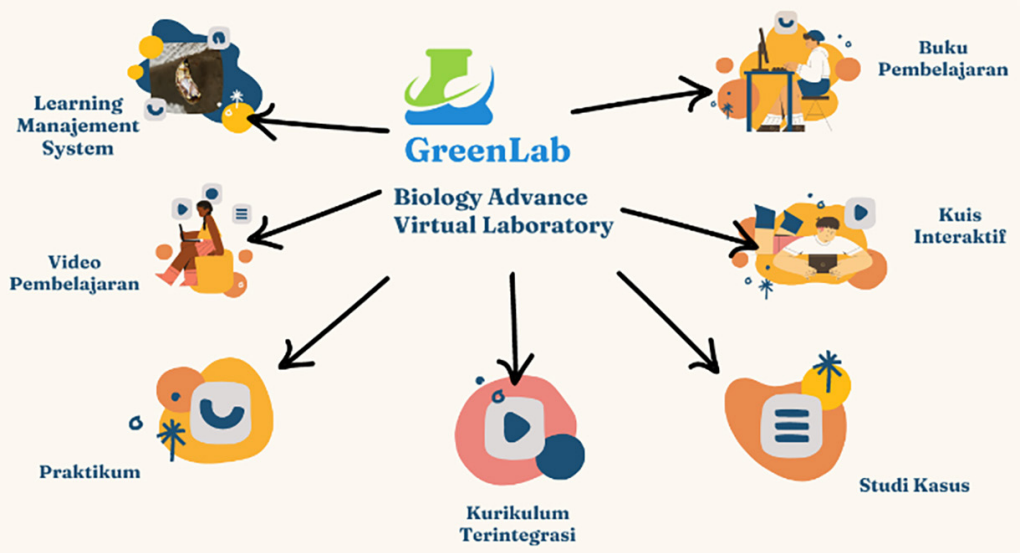

Fig. 1. Advanced biology concepts

The learning management system (LMS) facilitates online learning and includes supporting features. The learning management system service provides visual learning materials through educational videos. The learning videos combine STEAM elements and advanced biology concepts. Existing learning materials promote creative and innovative thinking among students. Practicum facilitates students in conducting experiments and making direct observations. Advanced biology concepts involve an integrated curriculum that promotes independent learning. Advanced biology education offers maximum advantages for students. This concept also includes case studies that facilitate students' understanding of the material based on real-life cases commonly encountered in the field. The interactive quiz feature can test students' understanding in an exciting and valuable way. The last concept is a learning book that provides detailed information about advanced biology material based on STEAM virtual laboratory learning.

3.3 Design of learning materials and media

The theoretical basis of the literature study results aligns with the data obtained from the field survey. Researchers organize educational materials based on students'

needs. The learning content will explore potential career paths and guide students towards their future careers. The following are the results of designing learning materials and media related to molecular genetics and synthetic biology (biotechnology). Material on molecular genetics and synthetic biology aims to increase knowledge of manipulating the genetic world. Molecular genetics provides information about the fundamental biochemistry underlying the inheritance of traits and cellular processes.

Meanwhile, synthetic biology combines biological principles with valuable techniques for designing, building, and modifying biological systems according to human desires. The sub-material in molecular genetic material includes the basics of molecular genetics, genetic coding, genetic mutation, genetic recombination, recombinant DNA technology, genomics, genetic regulation, development, cancer, and population genetics. Subtopics in synthetic biology include an introduction to the field, analysis of artificial biological systems, biocomponents, genome engineering, modeling and simulation, genetic circuits, protein expression, synthetic biology applications in health and energy, and ethical and legal considerations. The preparation of the material follows a systematic framework of thinking, making it easier for students to comprehend existing theories. The following material covers molecular genetics and synthetic biology.

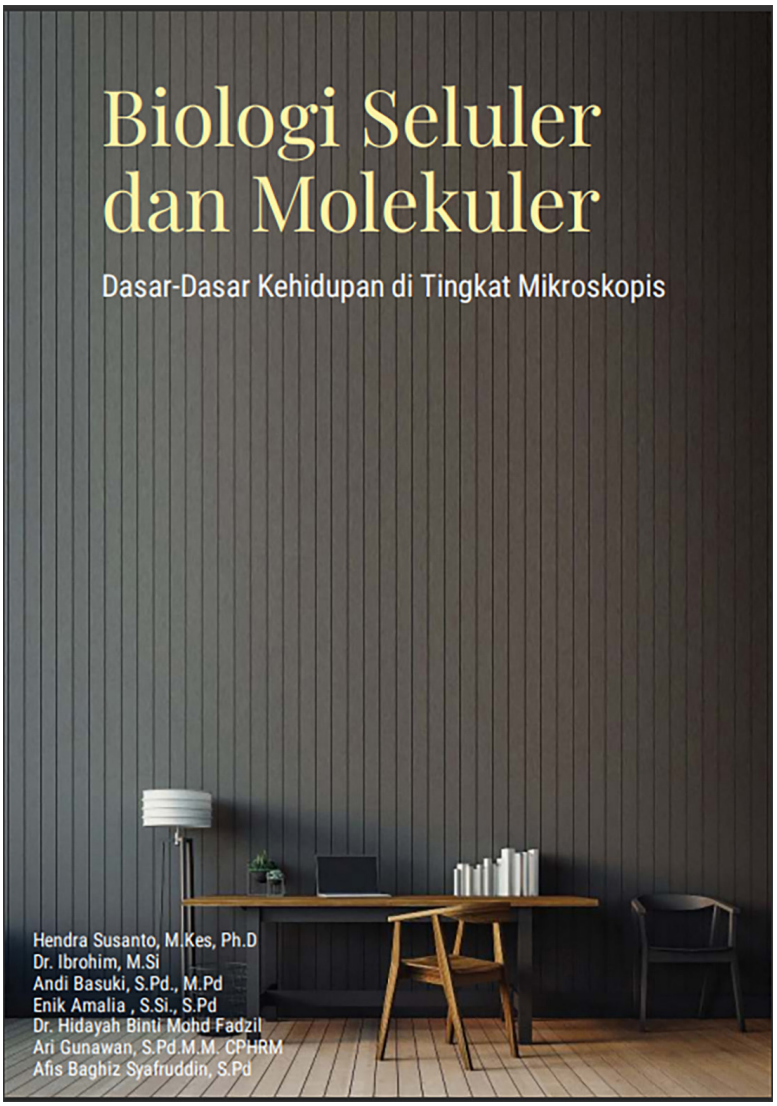

Fig. 2. Molecular genetics and synthetic biology learning materials

The material is compiled into interactive learning videos to enhance students' understanding. The following are educational videos on molecular genetics and synthetic biology:

Fig. 3. Learning video of molecular genetics and synthetic biology

3.4 Advance biology platform

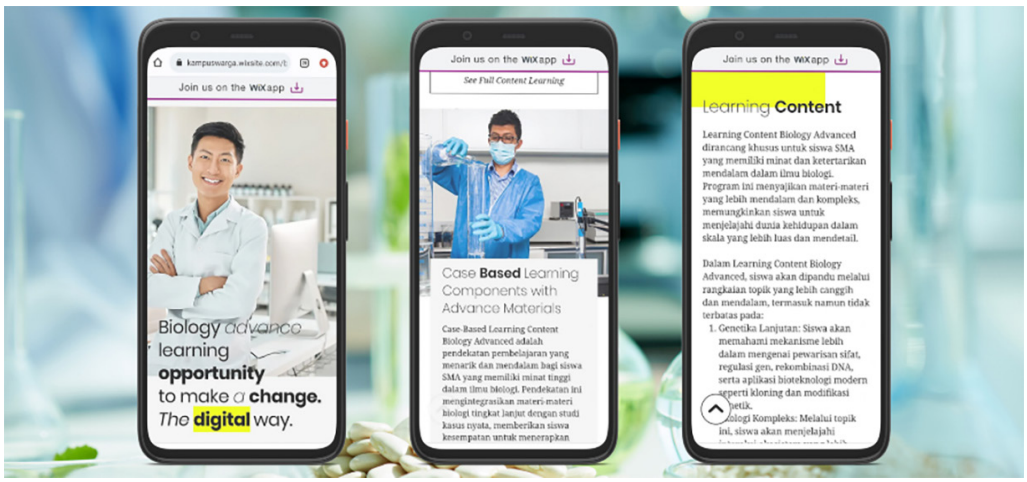

Fig. 4. Homepage display

This system is integrated into a learning development system to create advanced biology learning simulations (biotech, biochemistry, and biomedicine) based on STEAM virtual laboratory learning to support UM Laboratory High School as a research-based institution. This media platform consists of various supporting learning features and tools. The appearance is beautiful and creates an interactive

impression of cloud learning development. Data security is the primary consideration for later development.

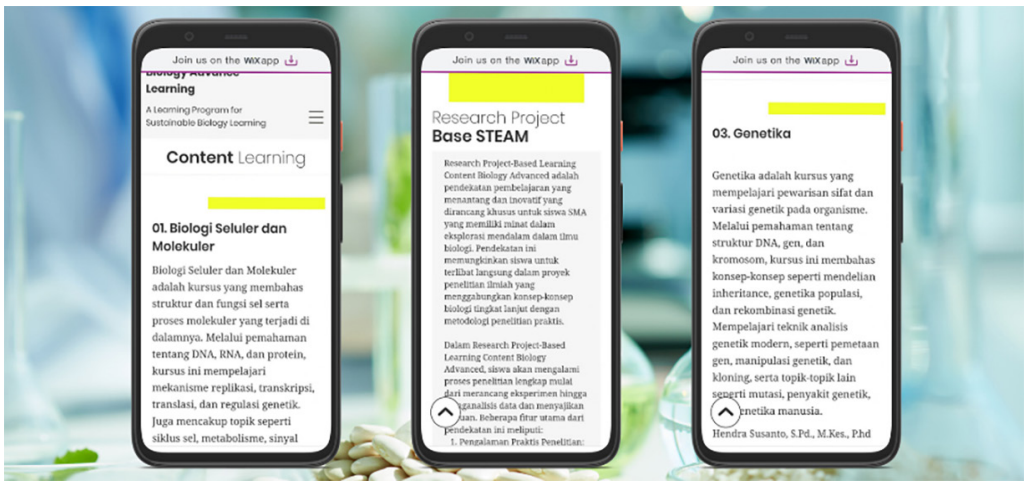

Fig. 5. Display of content learning

The "content learning" feature on the biology advanced learning website offers an interactive and comprehensive platform for biology students and teachers to access advanced learning materials. This feature offers a variety of learning modules, including text, images, videos, and animations, designed in an informative and in-depth manner to help users comprehend complex biology concepts. With an intuitive interface, users can explore various topics, run simulations, and access interactive content that supports active learning. This "content learning" feature enables users to learn autonomously. It provides easier accessibility to critical information in advanced biology domains, making it an effective tool in facilitating in-depth understanding and practical application in the field of biological sciences.

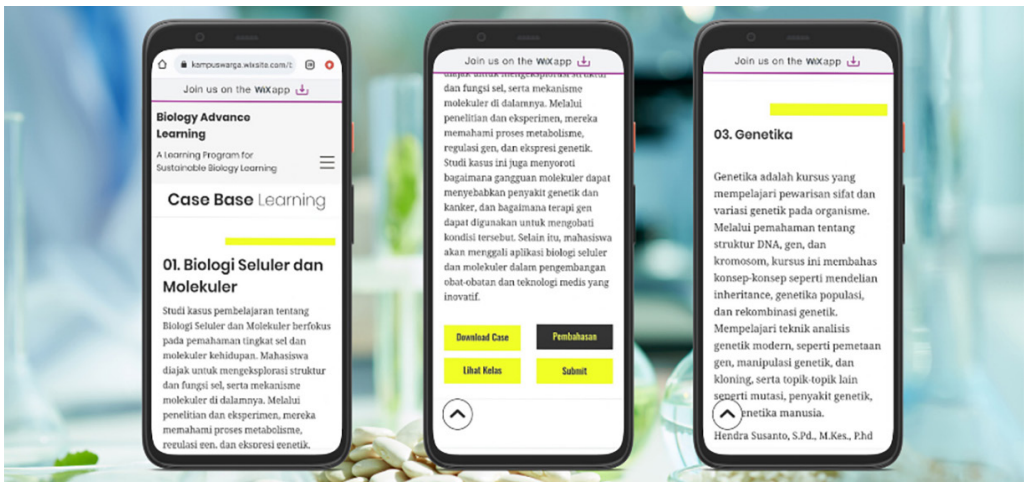

Fig. 6. Case-based learning

The primary function of the case-based learning feature on the Biology Advance Learning website is to provide users with a highly interactive learning experience through the application of a case-based learning approach. This feature allows users, including students and biology enthusiasts, to engage in analyzing and

comprehending biological concepts through the completion of real-life case studies. Case-based learning helps develop critical skills, problem-solving abilities, and the application of theory in practical contexts by enabling users to tackle complex real-world challenges. Users can experience contextual and relevant learning in the real world, bridging the gap between theory and application and encouraging the development of a robust analytical mindset to understand and address diverse biological challenges.

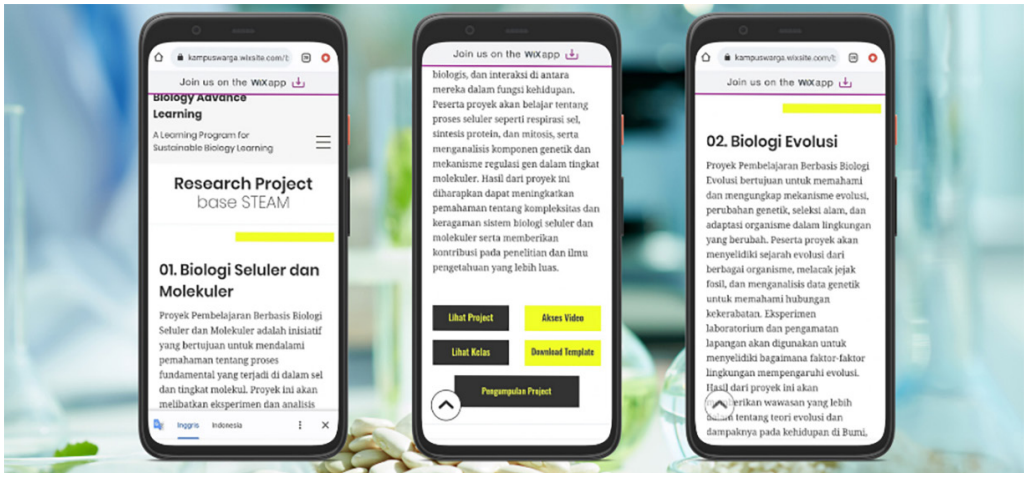

Fig. 7. View of the research project

The "research project base STEAM" feature on the biology advanced learning website opens the door to integrated learning experiences between biological sciences and cross-disciplinary approaches STEAM. This feature provides students with unique opportunities to engage in research projects that foster creativity and analytical thinking. They can design and conduct experiments, collect and analyze biological data, and incorporate cutting-edge technology to present their research findings. Existing learning features enhance students' comprehension of physical concepts. Existing learning media innovations enhance critical, collaborative, and innovative thinking skills.

3.5 Feasibility analysis of developed learning media

The study results have informed the development of learning media in the form of advanced biology learning websites. This involves a series of creative and technical processes aimed at presenting interactive and in-depth biology learning materials for advanced learners. This website facilitates the understanding of complex biological concepts, motivates scientific exploration, and enhances students' analytical and critical skills. The development process involves compiling comprehensive, advanced biology content [29]. The content includes in-depth explanations of theory, complex visual illustrations, and interactive simulations or animations to help students understand complex concepts. The latest data and findings in the field of biology can also be integrated so that the website always reflects the most recent developments in the biological sciences. Interactive features such as online quizzes, virtual lab simulations, and discussion forums enable students to actively engage in learning. This approach creates a more personalized learning experience and stimulates student participation in exploring biological concepts [30].

Advanced biology delves deeper into the fundamental concepts of biology and explores more intricate and profound aspects. The hallmark of advanced biology learning reflects its complexity and specificity as a constantly evolving branch of science. One of the main distinctive features of advanced biology learning is the emphasis on a deeper understanding of molecular and cellular concepts. Students learn about organisms at a macroscopic level and comprehend biological processes at the molecular level, including genetic regulation, protein synthesis, and intricate cellular interactions. Critical and analytical aspects are essential characteristics of advanced biology learning. Students are invited to develop problem-solving and critical thinking skills in analyzing scientific data, evaluating research, and designing experiments. This reflects the abstractness and complexity inherent in exploring biological sciences at an advanced level [31].

The validation analysis of advanced biology learning materials on the Advanced Biology platform comprehensively assesses the accuracy, significance, and relevance of the learning content. Validation of learning materials involves verifying the accuracy of the information presented. The material must have a solid scientific basis and be related to current discoveries in advanced biology [32]. This involves a review by biologists who have a deep understanding of the topics presented [33]. Validation also includes aspects of meaningfulness and clarity of content. Advanced learners should have a thorough understanding of learning materials, and scientific terms should be tailored to their level of expertise. The relevance of the material to the curriculum and learning objectives is an essential focus in validation analysis [34]. The material should cover topics that align with the requirements of the advanced biology curriculum and assist learners in attaining the specified learning objectives. Validation also considers the format and presentation of the material. Content should be presented in a format that supports active learning, such as visualization, simulation, or interactivity [36]. Aspects of platform interactivity, such as discussion forums or online quizzes, are also included in the validation analysis. These features should enhance learner participation and interaction in comprehending advanced biology concepts [35]. Analysis of the validation of the advanced biology learning materials on the advanced biology platform can result in a trusted, accurate, and valuable learning platform for students [37].

The validation analysis of advanced biology learning materials on the advanced biology platform involves a series of comprehensive evaluations to guarantee the quality, accuracy, and effectiveness of the materials. Visual quality can ensure that the video presented has high resolution, precise details, and attractive graphics [38]. This is to ensure that students can see and understand the content conveyed, especially in visual materials that require high detail [39]. Precise and high-quality audio is essential for students to clearly hear any information or explanation conveyed through the media [40]. A clear voice is crucial for comprehending and remembering the concepts taught. Textual learning materials should be written using appropriate, advanced-level language to minimize potential confusion [41]. The clarity of the text is essential for learners to read and understand the material smoothly. The content and context of the learning material must be interrelated and build on each other [42]. Understanding context helps learners relate advanced biological concepts to practical applications in the natural sciences, providing relevant and in-depth information. The advanced biology platform can ensure that the learning tools for advanced biology are adequate resources, provide rich learning experiences, and support students in developing an in-depth understanding of advanced biological sciences [43].

The validation analysis for advanced biology learning technology on the advanced biology platform aims to evaluate how well the technology meets quality

standards and supports effective advanced learning [44]. Analysis of technology functionality and reliability involves interactive features, simulations, or other technological elements that can enhance the learning experience [45]. The reliability of technology is a crucial factor in ensuring that the platform can be accessed and used without significant technical disruptions. Technology validation analysis also involves evaluating the security level of the platform [46]. The use of technology in learning requires robust data protection and privacy. Therefore, platforms must ensure that learners' data is safe and protected from potential security threats [47]. The advanced biology platform must be able to adapt learning materials based on the individual needs and progress of learners, creating a more personalized and relevant learning experience [48].

4 CONCLUSION

The results of developing an advanced biology learning website in STEAM-based biotech, biochemistry, and biomedicine include more in-depth learning materials. The advanced biology learning website consists of a homepage display, a content learning display, a case-based learning display, and a research project view. The results of this research have led to the development of the "Advance Biology" website, which contains various exciting features for students. This feature includes a homepage display, learning content display, case-based learning, and research project display. This platform provides engaging educational videos and comprehensive learning materials. The case studies on this site offer an overview of problem-solving and the current state of the industry. This media has validated learning materials, media, and technology in an excellent category.

5 ACKNOWLEDGEMENTS

The author thanks the LPPM (Lembaga Penelitian Dan Pengabdian Kepada Masyarakat) Universitas Negeri Malang for supporting the publication of the *International Journal of Interactive Mobile Technologies (iJIM)* with the title "Development of an advanced biology learning website in the fields of biotechnology, biochemistry, and biomedicine with the STEAM approach." This research was conducted through the Laboratory School Research Scheme in 2023, with contract number 5.4.508/UN32.20.1/LT/2023. Thanks to Mrs. Enik Amalia, S.Si., S.Pd., for her support and assistance in the learning implementation at the Laboratory High School, Universitas Negeri Malang.

6 REFERENCES

[1] A. Møgelvang, V. Vandvik, S. Ellingsen, C. B. Strømme, and S. Cotner, "Cooperative learning goes online: Teaching and learning intervention in a digital environment impacts psychosocial outcomes in biology students," *Int. J. Educ. Res.*, vol. 117, p. 102114, 2023. https://doi.org/10.1016/j.ijer.2022.102114

[2] R. Qin, L. K. Mahal, and D. Bojar, "Deep learning explains the biology of branched glycans from single-cell sequencing data," *iScience*, vol. 25, no. 10, p. 105163, 2022. https://doi.org/10.1016/j.isci.2022.105163

[3] C. Mandikonza, "Collaborative learning experiences and development of capabilities among first-year pre-service teachers learning Cell Biology concepts," *Soc. Sci. Humanit. Open*, vol. 5, no. 1, p. 100254, 2022. https://doi.org/10.1016/j.ssaho.2022.100254

[4] J. Zou, H. Li, and S. Plevritis, "Editorial: Artificial Intelligence, machine learning and the changing landscape of molecular biology," *J. Mol. Biol.*, vol. 434, no. 15, p. 167712, 2022. https://doi.org/10.1016/j.jmb.2022.167712

[5] A. Tyczewska, T. Twardowski, and E. Woźniak-Gientka, "Agricultural biotechnology for sustainable food security," *Trends Biotechnol.*, vol. 41, no. 3, pp. 331–341, 2023. https://doi.org/10.1016/j.tibtech.2022.12.013

[6] J. Formosinho, A. Bencard, and L. Whiteley, "Environmentality in biomedicine: Microbiome research and the perspectival body," *Stud. Hist. Philos. Sci.*, vol. 91, pp. 148–158, 2022. https://doi.org/10.1016/j.shpsa.2021.11.005

[7] J. J. Provost, "Increasing access for biochemistry research in undergraduate education: The malate dehydrogenase CURE community," *J. Biol. Chem.*, vol. 298, no. 9, p. 102298, 2022. https://doi.org/10.1016/j.jbc.2022.102298

[8] M. Kaess *et al.*, "Advancing a temporal framework for understanding the biology of non-suicidal self- injury: An expert review," *Neurosci. Biobehav. Rev.*, vol. 130, pp. 228–239, 2021. https://doi.org/10.1016/j.neubiorev.2021.08.022

[9] A. A. Pangestuti, "Penerapan Model Pembelajaran Biologi Berbasis Reading-Concept Map-Teams Games Tournaments Untuk Meningkatkan Kemampuan Berpikir Kritis Dan Hasil Belajar Kognitif Siswa Kelas X Ipa 4 Sma Laboratorium Um," *Pros. Semin. Biol.*, vol. 11, no. 1, pp. 963–968, 2014. [Online]. Available: http://jurnal.fkip.uns.ac.id/index.php/prosbio/article/view/4985.

[10] A. A. Masrida and I. Ifdil, "Kondisi Psychological Well-Being Siswa yang Berperilaku Konsumtif," *J. Apl. IPTEK Indones.*, vol. 4, no. 3, pp. 195–204, 2020. https://doi.org/10.24036/4.34381

[11] A. Kopf and M. Claassen, "Latent representation learning in biology and translational medicine," *Patterns*, vol. 2, no. 3, p. 100198, 2021. https://doi.org/10.1016/j.patter.2021.100198

[12] W. Hehakaya *et al.*, "Integrating STEAM with PjBL and PBL on biology education: Improving students' cognitive learning results, creative thinking, and digital literacy," *Biosf. J. Pendidik. Biol.*, vol. 15, no. 1, pp. 76–84, 2022. https://doi.org/10.21009/biosferjpb.24468

[13] A. P. Halim and F. Roshayanti, "Analisis Potensi Penerapan STEAM (Science, Technology, Engineering, Art, Mathematics) pada Kurikulum 2013 Bidang Studi Biologi SMA Kelas X," *Bioeduca J. Biol. Educ.*, vol. 3, no. 2, pp. 146–159, 2021. https://doi.org/10.21580/bioeduca.v3i2.6756

[14] L. Retnowati, S. Sugianto, and S. Alimah, "The development of integrated biology-entrepreneurship learning design based STEAM," *J. Innov. Sci. Educ.*, vol. 9, no. 3, pp. 124–129, 2021. https://doi.org/10.15294/jise.v9i3.40833

[15] A. Fitriyah and S. D. Ramadani, "Pengaruh Pembelajaran Steam Berbasis PjBL (Project-Based Learning) Terhadap Keterampilan," *J. Chem. Educ.*, vol. X, no. 1, pp. 209–226, 2021.

[16] Y. Suryaningsih, "Pembelajaran Berbasis Praktikum Sebagai Sarana Siswa untuk Berlatih Menerapkan Keterampilan Proses Sains dalam Materi Biologi," *Bio Educ.*, vol. 2, no. 2, p. 279492, 2017.

[17] M. Ligabo, F. C. Silva, A. C. da S. A. Carvalho, D. Rodrigues, and R. C. L. B. Rodrigues, "Practical way to apply fourth-generation assessment tools integrated into creating meaningful learning experiences in biology at high school," *Eval. Program Plann.*, vol. 96, p. 102155, 2023. https://doi.org/10.1016/j.evalprogplan.2022.102155

[18] R. Dimas Yusuf Septian Putra and Z. Abidin, "Pengembangan Media Website E-Learning Berbasis Model Responsive Web Design untuk Siswa SMA," *JKTP J. Kaji. Teknol. Pendidik.*, vol. 3, no. 3, pp. 292–302, 2020. https://doi.org/10.17977/um038v3i32020p292

[19] H. Priyatin and L. Septiana, "Perancangan Aplikasi Website E-Learning Menggunakan Model Spiral Pada SMP Diponegoro 1 Purwokerto," *J. Apl. Teknol. Inf. dan Manaj.*, vol. 2, no. 2, pp. 56–64, 2021. https://doi.org/10.31102/jatim.v2i2.1245

[20] M. Fadlan, I. T. Saputra, and S. Suprianto, "Pengukuran Usability Level Website E-Learning Pada Perguruan Tinggi Di Kalimantan Utara," *Sebatik*, vol. 26, no. 2, pp. 732–738, 2022. https://doi.org/10.46984/sebatik.v26i2.2058

[21] T. Roth, C. Conradty, and F. X. Bogner, "The relevance of school self-concept and creativity for CLIL outreach learning," *Stud. Educ. Eval.*, vol. 73, p. 101153, 2022. https://doi.org/10.1016/j.stueduc.2022.101153

[22] F. Ouyang and P. Jiao, "Artificial intelligence in education: The three paradigms," *Comput. Educ. Artif. Intell.*, vol. 2, p. 100020, 2021. https://doi.org/10.1016/j.caeai.2021.100020

[23] A. Soesilo and A. P. Munthe, "Pengembangan Buku Teks Matematika Kelas 8 Dengan Model ADDIE," *Sch. J. Pendidik. dan Kebud.*, vol. 10, no. 3, pp. 231–243, 2020. https://doi.org/10.24246/j.js.2020.v10.i3.p231-243

[24] G. Muruganantham, "Developing of e-content package by using ADDIE model," *Int. J. Appl. Res.*, vol. 1, no. 3, pp. 52–54, 2015. [Online]. Available: www.allresearchjournal.com.

[25] Yuanita and F. Kurnia, "Analisis STEM (Science, Technology, Engenering, and Mathematicss) Materi Kelistrikan Pada Buku Tematik Tema 3 Kelas 6 Sekolah Dasar," *STKIP Muhammadiyah Bangka Belitung*, vol. 1, pp. 1–8, 2019. https://doi.org/10.31000/sinamu.v1i0.2174

[26] W. M. Parinduri, "Penggunaan Media Pembelajaran Ipa Terpadu Berbasis Komputer Dengan Macromedia Flash 8 Pada Pokok Bahasan Unsur, Senyawa Dan Campuran Terhadap Kejelasan, Kedalaman Dan Ketepatan Isi Materi," *J. Sintaksis*, vol. 1, no. 1, pp. 1–8, 2019.

[27] E. Widyastuti and Susiana, "Using the ADDIE model to develop learning material for actuarial mathematics," *J. Phys. Conf. Ser.*, vol. 1188, no. 1, p. 012052, 2019. https://doi.org/10.1088/1742-6596/1188/1/012052

[28] L. W. Wardana *et al.*, "The impact of entrepreneurship education and students' entrepreneurial mindset: The mediating role of attitude and self-efficacy," *Heliyon*, vol. 6, no. 9, p. e04922, 2020. https://doi.org/10.1016/j.heliyon.2020.e04922

[29] D. Kamińska *et al.*, "Virtual reality and its applications in education: Survey," *Inf.*, vol. 10, no. 10, p. 318, 2019. https://doi.org/10.3390/info10100318

[30] N. Dahal *et al.*, "Development and evaluation of e-learning courses: Validity, practicality, and effectiveness," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 12, pp. 40–60, 2023. https://doi.org/10.3991/ijim.v17i12.40317

[31] R. Yang and W. Wei, "A systematic review of language MOOCs: Research design, evidence, and implications," *Journal of Educational Technology and Innovation (JETI)*, vol. 5, no. 2, pp. 33–47, 2023.

[32] Y. Rosen, I. Wolf, and K. Stoeffler, "Fostering collaborative problem solving skills in science: The Animalia project," *Comput. Human Behav.*, vol. 104, p. 105922, 2020. https://doi.org/10.1016/j.chb.2019.02.018

[33] D. W. Arumsari and W. Isnaeni, "Development of ICT oriented reproductive system materials learning module for training the high school students' information literature skill," *Journal of Biology Education*, vol. 12, no. 2, pp. 138–148, 2023. https://doi.org/10.15294/jbe.v12i2.50628

[34] I. K. Solekhah and A. Marianti, "Development of interactive Flipbook teaching supplement mechanism of heavy metal Toxicokinetic based on laboratory research," *Journal of Biology Eduation*, vol. 12, no. 2, pp. 162–168, 2023. https://doi.org/10.15294/jbe.v12i1.61380

[35] A. Procopio, G. Cesarelli, L. Donisi, A. Merola, F. Amato, and C. Cosentino, "Combined mechanistic modeling and machine-learning approaches in systems biology – A systematic literature review," *Comput. Methods Programs Biomed.*, vol. 240, p. 107681, 2023. https://doi.org/10.1016/j.cmpb.2023.107681

[36] S. M. Leksono, P. Marianingsih, E. N. Ilman, and N. Maryani, "Online learning media on biology conservation: Rawa Danau nature reserve website," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 8, pp. 87–100, 2021. https://doi.org/10.3991/ijim.v15i08.21567

[37] F. Daryanes, D. Darmadi, K. Fikri, I. Sayuti, M. A. Rusandi, and D. D. B. Situmorang, "The development of articulate storyline interactive learning media based on case methods to train student's problem-solving ability," *Heliyon*, vol. 9, no. 4, p. e15082, 2023. https://doi.org/10.1016/j.heliyon.2023.e15082

[38] Z. Zhicong, L. Heming, and Z. Jiaxian, "Teaching with social context in instructional video facilitates second language vocabulary learning," *Heliyon*, vol. 9, no. 3, p. e14540, 2023. https://doi.org/10.1016/j.heliyon.2023.e14540

[39] C. H. Liao and J. Y. Wu, "Learning analytics on video-viewing engagement in a flipped statistics course: Relating external video-viewing patterns to internal motivational dynamics and performance," *Comput. Educ.*, vol. 197, p. 104754, 2023. https://doi.org/10.1016/j.compedu.2023.104754

[40] S. L. Kuhlmann *et al.*, "How do students' achievement goals relate to learning from well-designed instructional videos and subsequent exam performance?" *Contemp. Educ. Psychol.*, vol. 73, p. 102162, 2023. https://doi.org/10.1016/j.cedpsych.2023.102162

[41] U. Cahyana, J. R. Luhukay, I. Lestari, I. Irwanto, and J. S. Suroso, "Improving students' literacy and numeracy using mobile game-based learning with augmented reality in chemistry and biology," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 16, pp. 4–15, 2023. https://doi.org/10.3991/ijim.v17i16.42377

[42] S. Flegr, J. Kuhn, and K. Scheiter, "How to foster STEM learning during Covid-19 remote schooling: Combining virtual and video experiments," *Learn. Instr.*, vol. 86, p. 101778, 2023. https://doi.org/10.1016/j.learninstruc.2023.101778

[43] A. Lehtinen, E. Kostiainen, and N. Piia, "Co-construction of knowledge and socioemotional interaction in pre-service teachers' video-based online collaborative learning," *Teaching and Teacher Education*, vol. 133, p. 104299, 2023. https://doi.org/10.1016/j.tate.2023.104299

[44] H. J. Kim and S. Y. Hwang, "Effect of website-based learning on improved monitoring of adverse drug reactions by clinical nurses," *Asian Nurs. Res. (Korean. Soc. Nurs. Sci).*, vol. 16, no. 1, pp. 45–51, 2022. https://doi.org/10.1016/j.anr.2021.12.004

[45] I. A. Alshalabi, S. E. Hamada, K. Elleithy, I. Badara, and S. Moslehpour, "Automated adaptive mobile learning system using shortest path algorithm and learning style," *Int. J. Interact. Mob. Technol.*, vol. 12, no. 5, pp. 4–27, 2018. https://doi.org/10.3991/ijim.v12i5.8186

[46] J. W. Gong, H. C. Liu, X. Y. You, and L. Yin, "An integrated multi-criteria decision making approach with linguistic hesitant fuzzy sets for E-learning website evaluation and selection," *Appl. Soft Comput.*, vol. 102, p. 107118, 2021. https://doi.org/10.1016/j.asoc.2021.107118

[47] I. Damopolii, T. Lumembang, and G. O. İlhan, "Digital comics in online learning during COVID-19: Its effect on student cognitive learning outcomes," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 19, pp. 33–47, 2021. https://doi.org/10.3991/ijim.v15i19.23395

[48] P. Borchert, K. Coussement, A. De Caigny, and J. De Weerdt, "Extending business failure prediction models with textual website content using deep learning," *Eur. J. Oper. Res.*, vol. 306, no. 1, pp. 348–357, 2023. https://doi.org/10.1016/j.ejor.2022.06.060

7 AUTHORS

Hendra Susanto is an Assoc. Professor and lecturer at Universitas Negeri Malang in the biology department, mathematics, and natural sciences faculty. He earned a Ph.D. in biological science and technology studies at National Chiao Tung University. He has expertise in molecular metabolic medicine, metabolic syndrome, and cancer (E-mail: hendrabio@um.ac.id).

Ibrohim is a Professor and lecturer at Universitas Negeri Malang in the biology department, mathematics, and natural sciences faculty. He earned the title of Dr. in biology education studies at Universitas Negeri Malang. He has expertise in biology learning transformation and biology teacher professionalism development (E-mail: ibrohim.fmipa@um.ac.id).

Andi Basuki is a Master and lecturer at Universitas Negeri Malang in the management department, faculty of economics and business. He obtained a Master's in Economic Education studies at Universitas Sebelas Maret. He has expertise in the field of ICT and learning media (E-mail: andi.basuki.fe@um.ac.id).

Hidayah Mohd Fadzil is an Assoc. Professor and lecturer at Universiti Malaya in the Department of Mathematics and Science Education Faculty of Education. He obtained a doctorate in science education studies at Universiti Malaya. He has expertise in science education, biology education, stem education, environmental education and sustainability, practical work science manipulative skills, and qualitative education research (E-mail: hidayahfadzil@um.edu.my).

Afis Baghiz Syafruddin is a Bachelor's student at Universitas Negeri Malang in the chemistry department, mathematics, and natural sciences faculty. He obtained a Bachelor's degree in Chemical Education studies at Universitas Negeri Malang. He has expertise in the field of learning technology and learning media (E-mail: afis.baghiz.1803316@students.um.ac.id).

Ari Gunawan is a Master. He is an alumnus of Universitas Negeri Malang in the management department, faculty of economics and business. He obtained a Master's degree in Management studies at Universitas Airlangga. He has expertise in the field of virtual reality and learning management systems (E-mail: ari.gunawan.1704126@students.um.ac.id).