Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Perceptions of Indonesian and Thai science lecturers on e-BIMO in science teacher education programs

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ARTICLE INFO

Article history:
Received 17 September 2024
Received in revised form
11 January 2025
Accepted 18 January 2025

Keywords:
Bioinformatics module
Science education
Pre-service teachers
Critical thinking
Interactive learning

ABSTRACT

The e-Bioinformatics Module (e-BIMO) was developed to address the needs of science lecturers and enhance pre-service science teachers' skills. This study examined the perceptions of nine science lecturers—seven from Indonesian universities and two from a Thai university—before and after implementing e-BIMO in science teacher education programs. Using qualitative methods, data were collected through genetic learning needs and experience interview sheets and analyzed using content analysis. Before implementation, discussions focused on curriculum, learning resources, teaching strategies, assessments, and conceptual understanding. Post-implementation results revealed that e-BIMO provided a more engaging and interactive learning experience, particularly in topics such as genetic diseases and forensic science, and helped pre-service teachers connect theoretical knowledge with practical applications, improving understanding and critical thinking. The study concludes by recommending the integration of e-BIMO into science teacher education programs, particularly in Indonesia and Thailand.

1. Introduction

Bioinformatics education is the teaching and learning of the use of computers and information technology, as well as mathematical and statistical analysis to collect, store, analyze, transform, and integrate data to solve biological problems (El Islami et al., 2023; Makolo et al., 2022). Generally, most bioinformatics teaching is carried out at the graduate level and in doctoral program training programs (Magana et al., 2014). In recent years, bioinformatics has been pushed into the undergraduate curriculum (Gatherer, 2020). However, many studies have found obstacles to implementing bioinformatics teaching, such as a lack of preparation of tutors and learners (Williams et al., 2019). Introducing bioinformatics at the bachelor's level of Science Education can address this problem. This is because graduates of bachelor's level of Science Education are pre-service science teachers who will enter school at the high school level, where, according to Attwood et al. (2019), the earlier computing skills are instilled, the more likely students are to maintain this knowledge and their confidence in the subject will increase. El Islami et al. (2023) also explained in their research that bioinformatics education is very closely related to the development of Artificial Intelligence (AI). You et al. (2022) explained that machine learning, a trendy subfield of AI, focuses on mining and identifying in-depth and actionable information from big and complex data using different types of networks. We know that bioinformatics is a field that often generates large amounts of data (You et al., 2022).

The implementation of bioinformatics education in this study uses e-BIMO (e-Bioinformatics Module) (bit.ly/e-Bimo). The Bioinformatics Module was previously made in the non-digital form in 2022, and

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e-BIMO follows the trend of Biology research so that it can meet the needs of students to learn more about Bioinformatics, especially for pre-service Biology teachers in the Bioinformatics Education Course. In addition, even though e-BIMO is sophisticated, updated, and contemporary, e-BIMO still pays attention to convenience and efficiency for its users, such as the use of interactive live worksheets, and biological databases that are free and freely available on the internet. This can support the effective implementation of e-BIMO technology. The e-BIMO that has been completed has been validated by several experts by looking at several criteria, such as the suitability of the material with an average score of 96, the implementation of CIbT gets an average score of 93, the presentation of the material gets a score of 100, the linguistics gets a score of 97, and in terms of graphics gets a score of 90. Based on the validation results, e-BIMO is feasible to proceed to the wide-scale implementation stage, which leads downstream that can be accessed at bit.ly/e-Bimo.

The limited research on Bioinformatics Education as an interdisciplinary of various fields of science is an urgency in this research. Given that bioinformatics is related to huge databases coexisting with humans at this time. This research tries to integrate e-BIMO learning into the curriculum in Indonesia and Thailand so that e-BIMO can be used globally. Universities in Indonesia and Thailand producing pre-service science teachers have similarities in learning activities, characteristics of science teachers, and technological conditions. The most important thing in implementing e-BIMO is an adequate internet network and student PCs on campus or in privately owned computer laboratories. The increase in biological databases is driving an increased need for those working in STEM fields (Wilkerson and Polman, 2020; Robeva et al., 2020; King et al., 2017). From the results of this study, we can find out the perception in the form of the needs of lecturers and pre-service biology teachers in response to genetics learning in the present and future, and the perception of lecturers after implementing e-BIMO to pre-service biology teachers is also associated with STEM literacy and computational thinking skills. Based on the background, this study aims to analyze the perceptions of Indonesian and Thai science lecturers before and after implementing e-BIMO in the science teacher education program.

2. Method

This study employed a qualitative descriptive research design to examine the perceptions of Thai and Indonesian science lecturers regarding e-BIMO in science teacher education. It focuses on their needs and views on genetics education, the learning tools commonly used at their institutions, and their experiences after implementing e-BIMO in genetics teaching.

2.1. Participants

The participants in this study were nine science lecturers, seven of whom were from two universities in Indonesia and two science lecturers from a university in Thailand. They were selected as informants on implementing e-BIMO (e-learning platform or digital curriculum).

2.2. Data sources

This study used in-depth interviews with science lecturers who already had teaching experience and/or observing before implementing e-BIMO with several questions consisting of curriculum for genetics learning, references in genetics learning, learning strategies and media, and assessments used in genetics learning, opinions on genetic concepts and Bioinformatic education. Further in-depth interviews were conducted after implementing e-BIMO by asking four questions about their experiences with e-BIMO on the genetic disease theme, e-BIMO on the forensic science theme, bioinformatics tools, and bioinformatics education.

2.3. Data analysis

Content analysis was used in the research based on interview results obtained by coding and identifying points and content that emerged related to lecturers' perceptions of e-BIMO. The data from the interviews we obtained before and after the implementation of e-BIMO from the three universities were then combined to obtain some common perceptions in the form of sentences. Some common perceptions we get are codes that produce important points that are interesting to discuss. The coding that we got and focused on before implementation consists of (1) Curriculum from each country affects the use of e-BIMO, (2) Learning resources and strategy of genetics concept must be varied and reliable, and (3) Learning outcomes in genetics concepts for pre-service science teachers. The coding that we got and focused on after implementation consists of (1) Genetic disease and forensic science themes engaging and relevant in e-BIMO, (2) Bioinformatics tools in e-BIMO are essential in helping students understand and analyze biological data, and (3) An e-BIMO is real-world application and skill development. Furthermore, to validate the points we got, we conducted a Focus Group Discussion (FGD) with three experts in STEM education, Bioinformatics Education, and Genetics.

2.4. Trustworthiness of the analysis

This study uses interview documentation at each location to produce transparent and objective data. In addition, a detailed recording of the research process is also carried out so that other researchers with similar results can repeat this study.

3. Results and discussion

3.1. Lecturers' perceptions on genetics and e-BIMO before implementation

3.1.1. Curriculum impact on e-BIMO

In Indonesia, the Independent Learning-Independent Campus (MBKM) curriculum provides students with flexibility to develop their skills based on their interests while gaining direct work experience (Adistana et al., 2024). A science lecturer explained that MBKM, introduced by the Ministry of Education and Culture of Indonesia (Kemendikbud), grants students greater autonomy in shaping their academic paths, allowing for a more diverse learning experience aligned with workforce demands and societal needs. In contrast, Thailand's curriculum varies across universities, with many adopting Outcome-Based Education (OBE). However, unlike in Indonesia, there is no centralized curriculum board governing university education.

The curriculum is vital for implementing e-BIMO, especially for science-related courses for pre-service science teachers. The characteristics of the curriculum in Indonesia and Thailand make it very possible to implement e-BIMO. This is due to the flexibility of the Merdeka Curriculum in Indonesia and the output-based curriculum in Indonesia and Thailand, namely Outcome-Based Education (OBE). OBE was rapidly adopted in educational institutions, which was considered a breakthrough to improve education worldwide it is a student-centered approach that focuses on measuring student performance through results including knowledge, skills, and attitudes. OBE expects freedom, and on the other hand, structured progress is predicted. One produces democratic knowledge, and the other produces capitalist knowledge management (Japee and Oza, 2021). The results of El Islami et al.'s (2023) study found that bioinformatics education is focused on undergraduate programs that integrate bioinformatics into biology courses, such as genetics and molecular biology, in science departments. Bioinformatics education is closely related to real-life activities, so biology learning, especially in molecular studies, can integrate social issues into the science curriculum (El Islami et al., 2023).

3.1.2. Diverse and reliable learning resources and strategies for genetics

Science lecturers in Indonesia and Thailand use various learning resources in teaching, including local and international textbooks, such as Campbell for genetics, journal articles, e-magazines, learning videos, and interactive tools. Science lecturers in Indonesia explained that in learning the concept of genetics, several learning resources can be used, namely books, modules, learning aids, videos and animations, interactive tools, and articles or journals science lecturers in Thailand specifically mentioned Campbell's book as the main reference. Interview results from both countries showed that the learning resources used for genetics are still general and lack variety. Thus, e-BIMO is one of the digital teaching materials that is suitable for use today. Specifically, it contains interesting themes to discuss with peers. The e-BIMO digital learning media is very fresh and full of technology because it utilizes bioinformatics devices available on the internet, such as SMS, NCBI, and Uniprot. BLAST from NCBI is the most widely used bioinformatics tool. Sari et al. (2022a) found that using BLAST in NCBI on the concept of molecular genetics can improve high school students' computational thinking. Students are also well-accepted in integrating genomics and transcriptomics with computational and molecular biology in practical courses using cooperative teaching methods for students with heterogeneous backgrounds (Pucker et al., 2019).

The teaching strategies employed include case-based learning (Case Method), project-based learning (PjBL), and problem-based learning (PBL). Practicums and group discussions are commonly utilized to enhance students' understanding of genetics. A respondent from Thailand emphasized the importance of incorporating examples in quizzes, tests, and similar assessments when teaching genetics concepts. As educators preparing future science teachers, it is essential to develop a variety of questions and repeatedly test them to identify and address learning difficulties, ensuring student comprehension.

An interview respondent from Indonesia highlighted that effective teaching strategies often integrate multiple approaches to foster deep understanding and critical thinking. These include the PjBL model, PBL, the Case Method, laboratory practice, and differentiated learning. This aligns with findings from Li et al. (2020), who reported that project-based learning in collaborative groups, incorporating programming languages, enhances participants' laboratory skills, scientific presentation abilities, and experimental design competencies.

Similarly, a systematic review by Hizqiyah et al. (2023) found that PjBL improves students' biology education and their ability to apply biological concepts in real-life contexts. Additionally, e-learning tools have been shown to be effective in supporting PBL in bioinformatics education. According to Lim et al. (2009), integrating e-learning tools alongside various teaching strategies could enhance future educational practices in this field.

3.1.3. Learning outcomes in genetics for pre-service science teachers

Assessments are carried out in various ways, including individual and group assessments covering cognitive, affective, and psychomotor aspects. This assessment is carried out through written tests, projects, practicums, and peer assessments. In Thailand, assessments also include presentations and oral tests. One of the interview results from an

Indonesian science lecturer was: Assessment of student learning outcomes in genetics material carried out by covering three domains, namely affective, cognitive, and psychomotor. In the affective domain, observations are carried out to assess student activity and lecture participation.

Furthermore, cognitive assessments are carried out using test assessments through mid-term and final exams and assignments. In the psychomotor domain, assessments are carried out by assessing collaboration skills (peer assessments) and product assessments." One of the interview results from a Thai science lecturer, "Assessment of student learning outcomes in genetics material is carried out using Authentic assessment Questions and answers, Pre-test and post-test Workshops in class, Mid-semester assessments, Project assignments Project assessments, Interaction Discussions, interactions with students, and oral tests." Based on the interview results, science lecturers in Indonesia and Thailand have never measured STEM literacy and computational thinking like in e-BIMO. This will be an innovation and refreshment for pre-service science teachers in both countries. The importance of providing new and different assessments from before will stimulate the brain and mindset of pre-service science teachers in solving problems. It is important to measure STEM literacy achievements to equip them with the skills needed to contribute to solving environmental problems (Dewi and Hamdiyati, 2024). STEM literacy instruments and measurements are still very rare and new. According to Donmez (2020), measuring STEM literacy is important to fulfill STEM education practices and expectations. Djambong et al. (2018) found that students are interested in completing challenging tasks, the complexity of the problems that arise from this process, and possible paths for future investigation. The abilities that can be measured using the computational thinking test are abstraction, generalization, decomposition, algorithmic thinking, and logical reasoning (Araujo et al., 2019). Bioinformatics is a rapidly growing discipline that integrates mathematical and computational techniques with biological knowledge for applications in medicine, the environment, and other important aspects of life. It is one example of an emerging field that illustrates the need for greater focus on STEM integration in education (Yoon et al., 2022; Morris, 2023).

Genetics is a fundamental yet complex subject. Lecturers highlight the need for clear teaching methods and interactive learning tools to prevent misconceptions. Many students struggle with genetics due to its abstract nature.

A science lecturer from Indonesia explained that genetics is crucial for understanding broader biological concepts such as adaptation, evolution, and biotechnology. It includes both basic principles, such as Mendelian inheritance, and more advanced topics, including DNA replication, transcription, and translation. Therefore, it is essential to develop engaging and interactive teaching strategies. Case-based, project-based, and hands-on experimental approaches have proven effective in enhancing student comprehension. Additionally, integrating modern technology, using visual aids, and presenting information in real-world contexts can increase student interest and facilitate learning.

Similarly, a science lecturer from Thailand emphasized that understanding genetics also requires knowledge of mathematics, particularly probability and statistics. Since genetics is highly abstract, pre-service science lecturers must develop innovative teaching strategies to help students grasp these complex concepts effectively.

Current and pre-service science teachers' opinions about bioinformatics are important in describing the status of bioinformatics education in a country. It was found that bioinformatics, genetics, biological science, and information technology are closely related (Sari et al., 2022b). Irmak and Tüzün (2019) found that pre-service science teachers' perceived TPACK lies in the subject matter area of genetics, so it is important for pre-service science teachers to focus on specific subject areas so that they can provide more insight into the nature of TPACK and develop better pre-service science teachers' TPACK (Nuangchalerm, 2020; Nithitakkharanon and Nuangchalerm, 2022; Pratumsala and Nuangchalerm, 2023).

Based on the interview results above, e-BIMO is a solution to make learning abstract and complex genetic concepts easier and more innovative for pre-service science teachers. This is because e-BIMO has a "bioinformatics education" feature for pre-service science teachers to practice making genetic lesson plans following the patterns that have been done in e-BIMO themes. Pre-service science teachers on this page begin by practicing determining the learning outcomes of genetic concepts in high school, then continue by determining what bioinformatics tools will be used in the lesson plan. The next stage is to analyze and find research articles where the research method uses bioinformatics so that later, it can be applied as learning materials for genetic concepts. The next stage is to be able to determine the instrument to measure learning outcomes, with one example being measuring students' STEM literacy. The final stage, PSTs are asked to determine the learning design to be developed into a complete and complete lesson plan. In e-BIMO, several examples of learning designs are provided, such as Inquiry-based learning, Computational Inquiry-based Learning, Project-based Learning, and Problem-based Learning.

3.2. Lecturers' perceptions on genetics and e-BIMO after implementation

3.2.1. Engagement and relevance of genetic disease and forensic science themes in e-BIMO

Based on the interview results regarding the perception of science lecturers towards e-BIMO, learning how to use e-BIMO on the theme of genetic

diseases is very interesting and relevant to everyday life. Videos and supporting features in e-BIMO help students understand the concept of genetic diseases more easily. Students are invited to think critically through simulations and real cases, such as family tree analysis in cystic fibrosis. This helps them better understand the sequence of nitrogen bases and other genetic concepts. This gives us satisfaction where the perception of science lecturers in Indonesia towards e-BIMO is on target.

One of the Indonesian science lecturers explained that the theme of genetic diseases is very interesting because this theme is very related to everyday life. The videos presented on this theme have represented the concept of the occurrence of genetic diseases. Some cases are presented that stimulate students to think critically, where students must prove the concept in the video with the results obtained from using the SMS software on E-BIMO. Likewise, one of the Thai science lecturers explained that the lesson on genetic diseases using e-BIMO was interesting. The content is not too complicated. Many things need to be understood and learned from the video clips.

e-BIMO, on the theme of forensic science, provides an interesting experience for students, involving a simulation of solving real criminal cases. This material stimulates students' curiosity and understanding of using fingerprints and DNA analysis in forensics. Students use software such as BLAST and SMS to complete investigations, strengthening their ability to apply genetic concepts to forensic science. One of the Indonesian science lecturers explained that students looked very enthusiastic about using e-BIMO to solve forensic cases. Students listened carefully to the video about Forensic Science and DNA Fingerprints. Students explained the video shown, "An investigator will prove a criminal act," a short, clear, and easy-to-understand video. Associated with genetics, samples of the area at the crime scene were taken to be tested using PCR. Students were able to solve the problems given, although they were a bit confused when determining the results of their investigation. There are similarities in the samples of victims A2 and A4 (Fig. 1), possibly siblings, even though it could be that they should be the same person with different samples. So, it takes care to conclude the data.

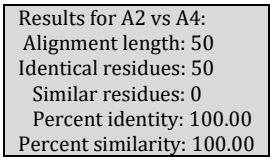

Fig. 1: Output of SMS

One of the Thai science lecturers explained that the lesson's content on the forensic science theme is more interesting than the genetics disease theme. Students are excited to read about forensic science and are more interested in matching the reading results with samples than activities in genetic disease lessons. Therefore, he said, "I think if the lessons are developed more in the future, lessons that are directly relevant to students will be more interesting than lessons that have medical knowledge or knowledge that is too far from students." This will make students more focused on the lesson using this program.

3.2.2. Importance of bioinformatics tools in e-BIMO for understanding and analyzing biological data

Using bioinformatics tools in e-BIMO is considered very important as a basis for solving various cases on genetics and forensics materials. This tool makes it easier for students to analyze biological data, such as calculating the number of nitrogen bases using SMS. In addition, this tool provides deeper insight into the application of bioinformatics in real life, strengthening students' technology and data analysis skills.

One of the Indonesian science lecturers argued that students can learn about various bioinformatics tools such as SMS and BLAST NCBI. Students can easily find out the number of nitrogen bases in a case using SMS without manually calculating them. One of the Thai science lecturers also thought that the e-BIMO program was interesting and could be used with biology students to help them understand how to read genetics more. He said, "But most importantly, I think the program will be even more valuable when it makes students realize that if the genetic code is too long and cannot be read manually, the program will be very important when reading the genetic code in this way. Finally, I think the lesson should be taught from this type of format first, which is easy to read, and then gradually increase the difficulty in the format that cannot be read manually."

3.2.3. Enhancing practical applications and skill development through e-BIMO

Bioinformatics education in e-BIMO is considered very important for the future, especially in connecting biological concepts with real life. By studying bioinformatics, students not only understand the theory but are also able to apply biological data analysis using digital tools, which are very relevant in today's digital learning era. This education also encourages critical thinking, collaboration, and realistic problem-solving skills (Sayres et al., 2018). One of the Indonesian science lecturers thinks that the presence of bioinformatics education will be very important in the future. In addition to being able to support increased knowledge at the application stage. It also helps to understand the concept of application of the basic materials taught. Moreover, for education, not only learning about theory but also bioinformatics, you can gain more understanding of cases, applications, and real events in society for the material presented One Thai science lecturer also thinks learning about this topic is very interesting. In Thailand, it may not

be widely used. It is taught at the junior high and high school levels. Teachers who must teach biology must understand the topic, but that is only a small part of the content, which is embedded in molecular genetics and DNA technology. However, this is an interesting topic and should be adapted to help students see the importance of learning about bioinformatics education.

3.2.4. The challenges of implementing e-BIMO

Based on the interview results, we highlight several challenges in implementing e-BIMO in Indonesia and Thailand, especially regarding technology access and curriculum alignment. Several urgent matters related to technology access and curriculum alignment in implementing e-BIMO in Indonesia and Thailand include limited infrastructure and devices, software familiarity, relevance to local contexts, and content complexity. In Indonesia and some areas in Thailand, restricted access to reliable devices and the internet affects the effectiveness of e-BIMO use. For example, e-BIMO's interactive and video-based content requires stable internet, which is not always available in all educational environments. Strengthened by Mahdi and Uyuni (2023), many remote areas in Indonesia have unstable internet networks. So, the government together needs to face this challenge by providing reliable devices and internet so that all students can access and use technology properly.

Regarding software familiarity, the tools in e-BIMO, such as BLAST and SMS, are still new to many students and even instructors. It takes time for students and educators to become comfortable with these tools, which is challenging in an environment with minimal technology training. This is reinforced by Boonmoh and Kulavichian (2023) and Muslimin et al. (2023) when associated with the SAMR framework (substitution, augmentation, modification, and redefinition), where substitution is the lowest level in technology use and redefinition is the highest level in technology use, Indonesia and Thailand are still mostly integrating technology at the substitution and augmentation levels (Boonmoh and Kulavichian, 2023). According to Amaditha et al. (2024), substitution is the level of technology use in learning that is still limited to a little use and application of technology in learning, as well as augmentation which is at the level of increasing the benefits of technology application. Therefore, to answer these challenges, one of which is professional development to train educators' technology use skills.

Curriculum alignment is closely related to the relevance of cases in e-BIMO to the local context. Effectively teaching bioinformatics requires instructors to have a solid understanding of the subject. In addition, bioinformatics content may need to be simplified for high school or introductory university courses, as the context is often too advanced without a fundamental understanding. Lecturers in Indonesia and Thailand recommended starting with basic genetics before moving on to complex bioinformatics to help students build the necessary background knowledge. Another recommendation is that including more locally relevant e-BIMO examples or cases can make bioinformatics feel more applicable and engaging to students. Some bioinformatics cases can also be related to neuroinformatics, the organization of neuroscience data, and the application of computational models and analytical tools.

4. Conclusion

The results before the implementation of e-BIMO discussed curriculum, learning resources, teaching strategy, assessment, and concept. After implementation, the results indicate that Thai and Indonesian science lecturers' perceptions indicate that e-BIMO provides a more engaging and interactive learning experience, especially in themes such as genetic diseases and forensic science. Additionally, this module helps pre-service science teachers interpret theoretical knowledge with practical applications, enhancing their understanding and critical thinking skills. The results recommend implementing the e-BIMO in science teacher education programs, especially in Indonesia and Thailand.

List of abbreviations

AI	Artificial intelligence
BLAST	Basic local alignment search tool
CIbT	Computational inquiry-based teaching
DNA	Deoxyribonucleic acid
e-BIMO	E-bioinformatics module
EFL	English as a foreign language
FGD	Focus group discussion
MBKM	Independent learning-independent campus (Merdeka Belajar Kampus Merdeka)
NCBI	National Center for Biotechnology Information
OBE	Outcome-based education
PCR	Polymerase chain reaction
PBL	Problem-based learning
PjBL	Project-based learning
SAMR	Substitution, augmentation, modification, redefinition
SMS	Sequence manipulation suite
STEM	Science, technology, engineering, and mathematics
TPACK	Technological pedagogical content knowledge

Acknowledgment

The authors thank the Directorate of Research, Technology, and Community Service, Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for funding this research through an applied research grant with contract number 092/E5/PG.02.00.PL/2024. This research is also financially supported by Mahasarakham University, Thailand.

Compliance with ethical standards

Ethical considerations

In this study, all participants were given complete information about the purpose, methods, potential risks, and benefits of the study before they gave written consent to participate. The identities and personal information of the participants will be kept confidential, and the data will be anonymized in the research report. In addition, participants were given the right to withdraw from the study at any time without negative consequences.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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