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Bioinformatics Data-Based Lecture Modules on the Topic of Phanerogamae Diversity to Empower Student Research Skills

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ABSTRAK

Penelitian ini dilatarbelakangi oleh rendahnya keterampilan penelitian di lingkungan mahasiswa. Padahal keterampilan ini merupakan salah satu kompetensi yang sangat dibutuhkan untuk keberhasilan secara akademik maupun karir. Penelitian ini bertujuan untuk memberdayakan keterampilan penelitian mahasiswa menggunakan modul berbasis data bioinformatika khususnya pada keanekaragaman Phanerogamae. Penelitian ini menggunakan metode campuran dengan desain sekuensial eksploratif. Subjek yang terlibat dalam penelitian ini yaitu 101 mahasiswa Pendidikan biologi. Pengumpulan data dilakukan dengan wawancara, analisis dokumen, open-ended question, dan kuesioner. Analisis data menggunakan deskriptif, paired sample T-test dan N-Gain score. Hasil penelitian menunjukkan bahwa modul terbukti layak digunakan dalam perkuliahan berdasarkan penilaian oleh ahli materi, ahli media, dan dosen praktisi mata kuliah. Modul yang dikembangkan terbukti efektif dalam memberdayakan keterampilan penelitian mahasiswa dengan perbedaan yang signifikan antara nilai pre-test dan post-test, dan respon mahasiswa terhadap modul tergolong positif. Implikasi penelitian ini adalah bahwa modul yang dikembangkan dapat menjadi bahan ajar inovatif dalam perkuliahan untuk menarik minat belajar mahasiswa serta mengakomodasi pelatihan research skills.

ABSTRACT

This research was motivated by the low level of research skills among students. At the same time, this skill is one of the competencies needed for academic and career success. This study aims to empower students' research skills using bioinformatics data-based modules, especially on Phanerogamae diversity. This study used mixed methods with an exploratory sequential design. The subjects involved in this study were 101 biology education students. Data was collected through interviews, document analysis, open-ended questions, and questionnaires. Data analysis used descriptive, paired sample T-test and N-Gain score. The results showed that the module proved feasible to use in lectures based on the assessment by material experts, media experts, and course practitioner lecturers. The developed module proved effective in empowering students' research skills with a significant difference between pre-test and post-test scores, and student responses to the module were positive. This study implies that the developed module can be an innovative teaching material in lectures to attract student interest in learning and accommodate research skills training.

1. INTRODUCTION

Phanerogamae diversity is one of the materials studied in the Biology or Biology Education department (Breman et al., 2021; Chen et al., 2020), namely in the Phanerogamae Diversity and Classification course or similar courses such as Plant Systematics or Higher Plant Systematics. This course emphasizes using research skills in learning (Saptasari et al., 2021; Wen et al., 2023). Research skills are a person's ability to create new concepts and understanding using data collection. This skill also involves finding answers to questions or solutions to a problem by gathering information(Maddens et al., 2021; Nurlaelah et al., 2020). Research skills are one of the competencies and abilities students need to develop to conduct quality research in academic activities (Kaur et al., 2023; Maddens et al., 2021). Developing research skills is essential to strengthen understanding of biological concepts and produce quality research (Kang et al., 2022; Kwangmuang et al., 2021).

However, the facts on the ground show that students' research skills differ from what is expected. Based on the initial detection of student research skills, it is known that students have research skills in the

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medium category, with an average of 72.35. Some literature also shows that research skills among students still need improvement. Based on research data, the average level of mastery of research design skills reached 51.3%, carrying out research was 55.21%, and reporting research results was 62.82% (Acharya et al., 2023; Servado, 2024). Meanwhile, research skills show low performance, with an average score of 12 out of 30 (Mydin et al., 2021; Ramli & Muchsini, 2019). The results of measuring the research skills of Biology Education students based on gender show no significant differences between men and women in all indicators of research skills (Maddens et al., 2023; Sukri et al., 2023). Students often need help in various aspects, such as literature review, data collection and analysis, and manuscript writing, which can hinder their ability to produce high-quality research results (Morris et al., 2021; O'Dea et al., 2021).

Students research skills are thought to be influenced by several factors, including the curriculum, learning strategies and methods, the media and learning resources used, and experience (Arisoy & Aybek, 2021; Closs et al., 2022). Based on observations, it is known that lectures on Phanerogamae diversity, carried out with lectures, discussions, project assignments, and field practicums, still need to fully train research skills optimally. The teaching materials lecturers use as companions in teaching include PPTs, textbooks, e-books, and scientific articles from accredited national and international journals. The needs analysis results regarding the Phanerogamae Diversity and Classification module, or similar courses, show that the module used is practical. In contrast, a companion module in the form of an enrichment module for theoretical courses has yet to be made available. The available practicum modules do not train students to develop research skills optimally. Based on this, innovation to improve student research skills is the urgency of this research.

This study is supported by previous research, which states that students' research skills must be well-developed to ensure academic success and career readiness (Acharya et al., 2023; Carberry et al., 2021). Previous studies have examined research skills in various contexts, including qualitative assessment in first-year biology practicum and gender comparisons in university and the workplace (Ain et al., 2019; Salybekova et al., 2021). Further research highlights the significant influence of social skills and teamwork on the development of graduate students' research skills, with a notable percentage demonstrating mid-level proficiency (Lira et al., 2020; Tan et al., 2022).

Apart from existing research, this study has novelty value because it focuses on research skills regarding Phanerogamae diversity among undergraduate students (Provost et al., 2022; Thomas et al., 2022). Related to the innovative solutions that can be offered to improve these skills is the development of bioinformatics-based teaching materials. Bioinformatics-based modules provide valuable experience in large-scale data analysis, knowledge synthesis, and evaluation of research results (Golden, 2023; Ren et al., 2022). Biological databases are crucial for biodiversity research (Ball-Damerow et al., 2019; Blair et al., 2020). Modules incorporating bioinformatics data, basic programming, sequence alignment, and phylogenetic tree construction are essential (Chen et al., 2021; Kadri et al., 2022). Combining wet laboratory work with in silico research experiences over eight weeks exemplifies effective teaching strategies (Kruchten, 2020; Saleh et al., 2021). Integrating bioinformatics in learning modules represents a novel approach to improving students' research skills (Davis et al., 2020; Olson et al., 2023).

Based on this explanation, this study aims to evaluate the effectiveness of bioinformatics data-based modules on Phanerogamae diversity in improving students' research skills. This study represents an innovative approach to developing teaching materials that integrate bioinformatics data into the Phanerogamae diversity curriculum. By expanding students' understanding of Phanerogamae plant diversity and equipping them with essential research skills, this study aims to improve the research competencies of biology education students.

2. METHODS

This research uses an exploratory sequential mixed method design, which is a sequential/phased design, starting with collecting and analyzing qualitative data and then collecting and analyzing quantitative data (Closs et al., 2022; Creswell & Clark, 2018). The aim of collecting qualitative data in the first stage was to explore existing phenomena, and it continued in the second stage by collecting quantitative data to explain the relationship between variables found in the qualitative phase. The qualitative phase was carried out to explore the problems that arise in the Phanerogamae diversity course and look for alternative solutions to the problems found by developing a product. In the quantitative phase, testing was conducted on the products developed for students taking the Phanerogamae diversity course using a quasi-experiment with a one-group pretest-posttest design (Kwangmuang et al., 2021; Mydin et al., 2021). The population used to test the lecture modules developed were undergraduate students of the Biology Education study program at one of the universities in Surakarta. The sampling technique used was purposive sampling, so the research sample chosen was 3rd-semester biology education students taking the Phanerogamae

diversity course, which consisted of 101 students. The data collection methods used in this study were interviews, document analysis, open-ended questions, and questionnaires. Semi-structured interviews were conducted with lecturers teaching Phanerogamae diversity and classification courses or similar courses in the Biology/Biology Education department at universities in Surakarta to explore the problems that occur in plant diversity lectures. Next, validation of the module products developed was carried out by experts in the field of learning media, material experts, and course practitioner lecturers. The Research Skills indicators are presented in Table 1. And the grids of student response assessment instruments are presented in Table 2.

Table 1. Research Skills Indicator

Indicator	Description
Observing	Initiating research by observing and identifying existing issues
Questioning	Formulating research questions and clarifying the formulated issues
Planning	Employing appropriate methodology to seek sources of information/data aligned with the predetermined research objectives
Analyzing	Managing data acquired through the predetermined methodology and critically analyzing information/data
Communicating	Communicating research findings and applying them within real-world contexts

Table 2. Student Response Assessment Instrument Grid

Aspect	Indicator
Subject Matter	Systematics of module content
	Language and term suitability
Auxiliary Information	Suitability of sample questions and summaries
	The usefulness of evaluation at the end of the material
Affective Considerations	Features in the module that can motivate students to learn
	Interactivity
Pedagogy	The usefulness of the features in the module to improve the understanding of the material
Interface	Design and multimedia display
	Interesting module content
Navigation	How to use page switching in multimedia
Robustness	Ease of module when used
	Product durability that minimizes multimedia errors during use

Data analysis was carried out on qualitative data and quantitative data. Qualitative data from interviews and document studies were analyzed descriptively, while data from module feasibility tests were analyzed descriptively with percentages using the criteria guide in Table 3. Quantitative data from module testing results were analyzed using paired t-test parametric statistics to determine the difference between pretest and posttest scores. Meanwhile, the module's effectiveness is tested by calculating the normalized gain score (N-gain). The results of the student questionnaire responses regarding using the module were analyzed descriptively with percentages based on the assessment criteria presented in Table 4. Finally, the qualitative and quantitative analysis results were interpreted to obtain conclusions from the research.

Table 3. Module Feasibility Criteria

Completeness	Category
$P > 80\%$	Highly Feasible
$60\% < P \leq 80\%$	Feasible
$40\% < P \leq 60\%$	Marginal Feasible
$20\% < P \leq 40\%$	Not Feasible
$\leq 20\%$	Highly Impractical

Table 4. Student Response Assessment Criteria

Completeness	Category
85% ≤ P	Very Positive
70% ≤ P < 85%	Positive
50% ≤ P < 70%	Less Positive
P < 50%	Not Positive

3. RESULT AND DISCUSSION

Results

Interviews with resource persons who are lecturers who teach Phanerogamae diversity and classification courses or similar courses such as higher plant systematics, plant systematics, or Phanerogamae systematics show that learning is carried out using various models, methods, learning media, and assessment bases. The results of the interviews show that among them, several learning models are used in lectures, such as project-based learning (PjBL), which emphasizes students' ability to learn actively. In contrast, the methods often used are lectures and discussions. However, the learning method is less effective when lectures are more exciting and varied. Document studies were carried out to determine the characteristics of learning in Phanerogamae diversity and classification courses or similar ones. The results of the document study of the semester learning plan obtained results that were similar to what the resource person said during the interview, while the results of the analysis of teaching materials showed that the teaching materials used were English language textbooks with PowerPoint as the medium in theoretical lectures, while in practical lectures, practicum modules were used The practicum module contains procedures for carrying out practicums, a brief review of plant terminology, and a brief description of the families in Phanerogamae. Students are known to report practicum results with a written report reviewing the results of observations containing species names and pictures, descriptions, and references. Meanwhile, in the same department at different universities, students prepare reports in a format that starts with the practical objectives, theoretical basis, results and discussion, conclusions, and bibliography.

One of the factors that causes students' low research skills is the teaching materials used by lecturers. Based on the interviews and document analysis results, it is known that the teaching materials used are textbooks and ebooks, and PowerPoint is the medium. More teaching materials are needed, and the methods used in lectures are still considered conventional, so they cannot train research skills optimally. Therefore, based on exploring the implementation of lectures on Phanerogamae diversity and classification, teaching materials were developed in bioinformatics data-based modules to improve and empower students' research skills. This development results in a digital module packaged in flipbook form using the Heyzine flipbook marker (https://heyzine.com/). The module developed can be accessed online and is equipped with the results of field research at the Indrokilo Boyolali Botanical Gardens and bioinformatics data. The module consists of several parts, as shown in Figure 1, including (1) Introduction, which includes the front page (cover), table of contents, foreword, module description, concept map, learning outcomes, and instructions for using the module; (2) Contents, including; a brief description of the Indrokilo Botanical Gardens, chapters 1–5, project assignments and reflective journals at the end of each chapter; and (3) closing, including bibliography, glossary, and back page.

(a) (b) (c)

(d) (e) (f)

Figure 1. Front Cover (a), Table of Contents (b), Learning Outcomes (c), Material from Field Research Results (d), Exercises in the form of Mini Projects and Reflective Journals (e), Back Cover (f).

The product developed as a lecture module based on bioinformatics data on Phanerogamae diversity material to empower students' research skills was tested for validity to determine the level of feasibility of the module developed. Module validation is carried out through the expert judgment of someone with expertise in their field, including material experts, media experts, and educational practitioner experts. Based on the criteria guidelines, the assessment from the three module expert validators shows that the module is considered suitable for use because it has met a score above the minimum threshold for module suitability. The results of the media feasibility test are presented in Table 5, which shows an average score of 90.83% in the very feasible category.

Table 5. Media Feasibility Test Results

No.	Aspect	Average Score (%)	Category
1.	Material	85	Highly Feasible
2.	Construction	93.75	Highly Feasible
3.	Language	93.75	Highly Feasible
	Average	**90.83**	**Highly Feasible**

The results of the material feasibility test are presented in Table 6, which shows that the average score is 87.92%, so the module developed is feasible in terms of material or content. The module developed contains several sub-materials about Phanerogamae diversity, including (1) examples of Phanerogamae plants based on the results of field exploration at the Indrokilo Boyolali Botanical Garden; (2) identification and classification; (3) phenetics and phylogenetics; (4) bioinformatics data; and (5) phylogenetic tree reconstruction using bioinformatics data. The module developed contains the field research results to present concrete examples that can contextualize the learning process. Finally, a feasibility test was carried out on educational practitioners, namely lecturers who teach Phanerogamae diversity courses or similar courses, the results of which are presented in Table 7. The validation results show an average score of 90.42% in the highly feasible category, so the module developed can be considered practical and suitable for use as accompanying teaching material in Phanerogamae diversity lectures.

Table 6. Material Feasibility Test Results

No.	Aspect	Average score (%)	Category
1.	The Truth of the Content of the Material	100	Highly Feasible
2.	Free from Conceptual Errors	75	Feasible
3.	Novelty of Material	83,33	Highly Feasible
4.	Coverage and Depth of Material	81.25	Highly Feasible
5.	Reference Suitability	100	Highly Feasible
	Average	**87.92**	**Highly Feasible**

Table 7. Results of Feasibility Tests by Practitioner Lecturers

No.	Aspect	Average score (%)	Category
1	Material	90	Highly Feasible
2	Construction	87.75	Highly Feasible
3	Language	93.75	Highly Feasible
	Average	**90.42**	**Highly Feasible**

The effectiveness test of the module was carried out with a one-group pretest-posttest design on a group of students taking the Phanerogamae diversity and classification course, consisting of 101 students. The results of obtaining research skills scores on the pretest and posttest are presented in Figure 2. There was an increase in the posttest score compared to the pretest, with an average pretest score of 72.59, while the average posttest score was 85.78, so there was an increase in the average score of 13.19. This shows that overall, there is an increase in students' research skills scores after implementing the high plant diversity lecture module based on bioinformatics data. Data analysis was conducted using parametric statistical tests, specifically the paired sample t-test. Prior to this, normality and homogeneity tests were performed using SPSS version 25, confirming that the data was normally distributed and homogeneous (significance value > 0.05). The paired sample t-test results, shown in Table 8, indicated a significance value of 0.000 (< 0.05). Thus, H_0 is rejected, and H_a is accepted, demonstrating a significant improvement in students' research skills after using the bioinformatics data-based lecture module.

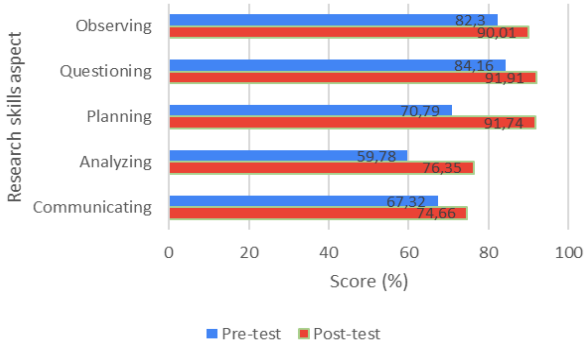

Figure 2. Average Pre-Test and Post-Test Scores for Each Research Skills Indicator

Table 8. Results of the Paired Sample T-test

Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Lower	95% Confidence Lower	t	df	Sig. (2-tailed)
-11.56218	5.78379	0.57551	-12.70397	-10.42039	-20.090	100	0.000

Finally, the normalized gain score (N-gain score) was calculated to determine the effectiveness of the plant diversity lecture module based on bioinformatics data in improving students' research skills. The results of the N-gain values for students of 3 classes are presented in Table 9. Based on Table 9, the increase in students' research skills after using the Phanerogamae diversity module based on bioinformatics data shows a moderate level for all experimental classes, so the lecture module developed is considered adequate for empowering students' research skills. Student responses to learning using the developed Phanerogamae diversity module were also analyzed to improve the module in the future. The results of the response questionnaire distributed to students are presented in Table 10, which shows that students responded positively to the module developed with average student response from all aspects is included in the positive category.

Table 9. N-Gain Value in Each Class

Group	N-Gain Score	Interpretation
A	0.41	Median
B	0.35	Median
C	0.47	Median

Table 10. Student Responses to Using the Module

No.	Aspect	Average Score (%)	Category
1	Subject Matter	84.53	Positive
2	Auxiliary Information	81.59	Positive
3	Affective Considerations	83.15	Positive
4	Pedagogy	84.54	Positive
5	Interface	83.14	Positive
6	Navigation	85.81	Very Positive
7	Robustness	85.03	Very Positive
	Average	**83.97**	**Positive**

Discussion

The transformative potential of teaching materials developed from research findings is increasingly recognized in biology education. The importance of integrating theoretical knowledge with empirical evidence, providing students with contextual and engaging learning experiences, cannot be overstated. In particular, the incorporation of bioinformatics data into educational modules is a prime example of this approach (Lidiawati et al., 2021; Wulandari et al., 2022). By utilizing bioinformatics data, educators move away from traditional pedagogical approaches that focus only on morphological characteristics, but instead explore the complex diversity of Phanerogamae (Mydin et al., 2021; Xiao et al., 2023). Additionally, bioinformatics data is used to develop modules that start with basic programming skills and progress to more advanced topics, such as sequence alignment and phylogenetic tree construction, as tasks in the module progress. This is in line with research stating that there is potential for bioinformatics data to enhance student learning experiences and encourage a deeper understanding of Phanerogamae diversity.

Bioinformatics enables the research, development, and application of computers and computational tools to handle and improve the management of biological data (Rodríguez et al., 2021; Sukenda et al., 2019), thereby offering many opportunities for educational innovation. In addition, integrating bioinformatics into learning allows students to engage with significant and authentic scientific data sets and tools, making it possible to develop computational and technological competencies that support the development of students' research skills. Research skills are competencies or skills that can be trained by applying learning theories, namely learning based on experience, constructivist alignment, and self-efficacy (Jordan et al., 2021; Lachance et al., 2020). Students research skills can be improved through student participation in scientific practice because research skills training cannot be separated from direct experimental or exploratory activities in building understanding in science learning (Carberry et al., 2021; Vieno et al., 2022).

The importance of incorporating skills training into required coursework and providing students with opportunities to engage in structured learning experiences such as reading scientific literature, making presentations, or writing proposals (Lachance et al., 2020; Servado, 2024). Practical work and authentic research activities have been proven to contribute to developing laboratory skills, scientific knowledge, and understanding of scientific concepts, which play a role in developing research skills (Shana & Abulibdeh, 2020). It is known that students identify research skills that they believe will be important in their future professions and everyday life. Research skills training integrated with bioinformatics technology can develop skills needed in the world of work. The results of this study are in line with a survey conducted by the Pew Research Center which shows that 87% of workers in the United States say that research skills are necessary for their jobs (Arisoy & Aybek, 2021; Jordan et al., 2021)

In this research, the module is designed to teach students about the use of bioinformatics in studying and understanding the diversity of Phanerogamae plants based on data from NCBI (Sukmawati et al., 2022; Wulandari et al., 2022). Through this module, students are expected to develop practical research skills and a deeper understanding of the diversity of Phanerogamae plants. Modules are also packaged in digital form to make it easier for students to learn anytime and anywhere (Chimmalgi & Hortsch, 2022; Puspita et al., 2024). The development of interactive digital teaching materials containing various multimedia content can be an innovation in training students' research skills. Audio-visual and multimedia-based learning media are more popular than conventional media that are commonly used (Endris & Suhartini, 2022; Sukenda et al., 2019). Apart from that, multimedia-based learning media can provide visual, dynamic, and interactive images as well as an understanding of biology that students can receive (Saleh et al., 2021; Sukenda et al., 2019). These results are supported by previous research which states that the use of interactive teaching materials such as PBL-STEM integrated e-modules, interactive videos, and other

innovative tools has proven effective in improving students' research skills (Dare et al., 2021; Servado, 2024).

In addition, teachers can train students' research skills by implementing various teaching strategies, one of which is project-based learning, which requires students to explore, assess, interpret, synthesize, and provide information to produce various learning outcomes. (Kaur et al., 2023; Salybekova et al., 2021). Another study focused on the influence of project-based learning on graduate students' research proposal writing skills, showing significant improvements in scientific research skills (Breman et al., 2021; Khalaf & Alshammari, 2023). Additionally, project-based learning has motivated students to learn research methodology skills and enhance their competency in qualitative research in social work doctoral education (Vieno et al., 2022; Yang et al., 2019). Therefore, implementing project-based learning can be a valuable effort for lecturers to improve students' research skills.

This research also highlights the importance of technology integration in developing research skills. Digital tools and online platforms have expanded students' access to information sources, facilitated collaboration between fellow students and faculty advisors, and provided opportunities to develop data analysis skills relevant to their field of study. This is supported by the opinion that information technology has an important role in supporting research-based learning in this digital era (Haleem et al., 2022; Sukri et al., 2023). Therefore, improving students' research skills requires developing an adequate curriculum and adapting to constantly changing technological developments. By providing students with authentic research experiences and engaging them in hands-on activities using real-world data, educators can effectively enhance students' research skills and foster a deeper understanding of complex biological concepts (Dare et al., 2021; Endris & Suhartini, 2022). Moreover, using digital teaching materials and multimedia resources further enriches the learning experience, catering to students' diverse learning styles and preferences.

This study has several significant advantages, such as improving students' data analysis skills and in-depth understanding of biodiversity through practical approaches and modern technology (Khalaf & Alshammari, 2023; Sukenda et al., 2019). The implication is that implementing this module can empower students' research skills and prepare them to face more complex scientific research challenges. But of course, this study still has shortcomings, such as limited student access to the necessary bioinformatics software and the need for additional training for lecturers to master this technology. For future research, it is recommended that a long-term evaluation of the effectiveness of this module, the development of more comprehensive supporting materials, and the improvement of technological infrastructure in educational institutions be conducted.

4. CONCLUSION

In conclusion, this research emphasizes the importance of integrating bioinformatics data into teaching materials to enhance students' research skills and deepen their understanding of Phanerogamic diversity. The effectiveness of bioinformatics-based modules is evident in the significant improvement in students' research skills post-implementation, coupled with positive student responses to multimedia-based learning resources. Future research could explore enhancements to teaching methods like project-based learning and leverage evolving technologies to improve research skill development in biology education further. By embracing ongoing advancements, educators can continue to empower students and drive innovation in biology education.

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