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Developing a PBL Based E-Module on Plant Structure and Development Subject with Formative Assessment to Improve Students' Collaborative Problem-Solving (CPS) Skill

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ABSTRACT
Collaborative problem solving (CPS) is a learning activity in which students work in small groups to achieve common goals. Students' CPS skills can be assessed through observation, self-assessment, and peer assessment. To enhance CPS skills, the Problem Based Learning (PBL) model can be applied. This study aims to develop a PBL-based e-module on Plant Structure and Development specifically on pollination and fertilization with self-assessment and peer assessment to improve the students' collaborative problem-solving skills. The research and development method in this study follows the pattern established by Lee and Owens. The population of this study consisted of Biology Education students at UM (Universitas Negeri Malang) and students from private universities in Malang. Purposive sampling was used for sample selection. The instruments used were survey and questionnaire. Based on the results of pre-test and post-test, it can be concluded that the use of the e-module can improve the students' CPS skills. Based on the validity, practicality, effectiveness tests; as well as implementation of the learning syntax, it is known that the e-module is valid and practical without any revisions, moderately effective, and very good in terms of the implementation of the learning syntax.

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1. INTRODUCTION

PISA (OECD, 2017) defines collaborative problem-solving (collaborative problem-solving) skill as an individual's skill to solve problems together with other individuals by gathering all the knowledge, skills, and efforts from each individual involved to find a solution for the given problem. On the other hand, other researchers define collaborative problem solving as a learning activity in which students work in small groups while studying mathematics to achieve common goals (Albert & Kim, 2013).

The assessment of students' collaborative problem-solving skills can be done through observation and formative assessment, which includes self-assessment and peer-assessment. Self-assessment is defined as a process in which students take responsibility for evaluating their own learning outcomes or participating in identifying criteria or standards to be applied in learning and making decisions regarding the achievement of those criteria and standards (Boud, 2013). Meanwhile, peer-assessment is a process in which students provide formative or summative feedback to their peers in terms of the work or tasks they have completed (Chin, 2016). Based on research conducted by Pratiwi *et al.*, (2020), peer-assessment can effectively assess students' collaborative skills; while according to Sari *et al.*, (2018) and Ramos Salazar & Hayward, (2018), self-assessment can be used to assess students' problem-solving skills.

Collaborative problem-solving skills are as important for students as 21st-century skills. However, OECD, (2016) find that the level of collaborative problem-solving of the students is still low. Based on the research conducted by Fuad *et al.*, (2019), the collaborative problem-solving skill of elementary school teacher wannabe is still at a low level due to the inadequate learning models used to enhance their collaborative problem-solving skill. Additionally, according to Xu *et al.*, (2022), the underdevelopment of collaborative problem-solving skills among engineering students is attributed to the lack of learning media available for students to use in their learning process.

The low level of collaborative problem-solving skill also occurs among students at Universitas Negeri Malang, especially the ones who take the Plant Structure and Development course. The success of collaborative problem-solving skills is related to students' cognitive learning outcomes. Based on interviews with the lecturers of Plant Structure and Development class, it was stated that Plant Structure and Development 2 students only got 2.8 score of 4, which indicated a low level of achievement.

To improve the students' collaborative problem-solving skills, it is necessary to have a teaching module that can enhance these skills. Based on the needs analysis, students agreed to the development of an e-module for Plant Structure and Development course. The lack of a more complex module in the course on plant developmental structures is another key justification for creating the e-module. As a result, the researcher is creating an e-module as a teaching tool through this research that is easily accessible and includes more complex materials. Therefore, through this research, the researcher develops an e-module as a teaching resource. Through the development of a PBL-based e-module, it is expected that students can better understand the focal point of the learning process, thereby enhancing their collaborative problem-solving skill in solving problems collaboratively.

2. RESEARCH METHOD

The study conducted is a type of development research aimed at creating an E-Module on Plant Developmental Structures with formative assessment, with the objective of enhancing students' collaborative problem-solving skills. The Lee & Owens (2004) model served as the framework for this research and development study, employing a quasi-experimental method and simple random sampling techniques. The quasi-experimental method in this research involves the random selection of both experimental and control classes. The fact that it was designed with consideration for creating multimedia learning modules influenced the decision to follow this framework. An interactive problem-based e-module media product using Google Sites was developed, evaluated, and validated using this paradigm for the Plant Structure and Development course. The descriptions of the five steps of development are as follows.

Step I: Analysis. The first step is analysis, which consists of two sub-steps: needs analysis and front-end analysis. Interviews, observations, and both written and oral tests were used to determine the required services. In this stage, the researcher conducted interviews with the lecturers of the Plant Structure and Development course, followed by observations and written tests for the students of Universitas Negeri Malang who had taken the Plant Structure and Development course previously. This was done to identify issues related to teaching materials or learning sources and the students' skills during the course. The initial and final analyses consisted of several analyses, including "audience analysis, technology analysis, situation analysis, task analysis, critical analysis, objective analysis, issue analysis, media analysis, extended data analysis, and cost analysis" (Lee & Owens, 2004).

Step II: Design. The media specifications for the e-module were designed during the design phase through completing several tasks, including creating a project timeline, media specifications, and content/learning material structure.

Step III: Development. In the third phase, known as development, the product was brought from the conceptual stage to actual existence through prototype creation. Content creation in this stage involved developing text, animation, images, videos, buttons, audio, and question creation. To establish the reliability of the developed product, a series of tests were conducted by various experts, including media experts and content experts. Expert evaluations served as benchmarks for measuring future product iterations. The following is an explanation of each sub-stage of e-module development for Plant Development Structure.

Step IV: Implementation. The fourth step was implementing the plan. After the validators verified the accuracy of the data, they were field-tested on the students enrolled in the Plant Structure and Development course. The purpose of product testing was to determine whether the e-module was successful in achieving its stated objectives of enhancing students' teamwork and problem-solving skills, as well as their cognitive learning outcomes.

Step V: Evaluation. Evaluation is the final step in the Lee & Owens development model. After the testing, evaluations were gathered through user surveys accompanied by evaluation tests. To evaluate the effectiveness of the e-module, the researchers compared pre-test and post-test scores. The information obtained from this phase was used as the basis materials for the final stage of product development. The general procedures of the evaluation stage include assessing response or reaction, knowledge evaluation, performance evaluation, and impact assessment (Lee & Owens, 2004).

Research instruments are defined by Sugiyono, (2009: 184) as tools used to quantify social phenomena which happen naturally and are studied experimentally. All these phenomena collectively are referred to as research variables. Thus, research instruments are data collection tools. The instruments used in this study included data collection sheets for validation, practicality, and effectiveness tests.

The collected data must be processed and analyzed promptly to determine whether the research objectives have been achieved or not (Arikunto, 2008). The data analysis in this study covered analysis on validation, practicality, and effectiveness; as well as the analysis on the implementation of learning syntax.

Data Validation Analysis

Both quantitative and qualitative data analysis methods were used in the study. The latter was specified on the use of descriptive qualitative. The obtained data were used to analyzed the validation scores provided by content experts and media experts by calculating the percentage of the e-module's validity scores as follows.

$$\textbf{User Validation} = \frac{\textit{Total Empirical Score}}{\textit{Maximum Total Score}} \times \mathbf{100\%}$$

The questionnaire assessment data from the validators were evaluated based on validity criteria, which were subsequently analyzed using the assessment criteria outlined in the following table:

Table 1. E-Module Validity Criteria

Percentage	Conclusion
81%- 100%	Highly valid, can be used without revisions
61%- 80%	Valid, can be used but requires minor revisions
41%- 60%	Less valid, not recommended for use as it needs significant revisions
21%- 40%	Not valid, should not be used, requires substantial revisions
1%- 20%	Highly not valid, should not be used

(Source: Sa'dun Akbar, 2017)

Qualitative data, in the form of comments and suggestions given by validators regarding the e-module were considered as materials for improving the e-module further.

3. RESULT AND DISCUSSION

Assessment/Analysis Stages

The assessment/analysis stage involves describing the issues in the learning process at the research site. This stage comprises two parts: needs assessment and front-end analysis. The outcomes of these two stages are described as follows.

1. Results of Needs Assessment

The data for the needs analysis were obtained through interviews with instructors of the Plant Development Structure course and observations within classes that had previously taken this course. Based on the interview results, it was found that the Plant Development Structure course still faced challenges in enhancing students' Collaborative Problem-Solving (collaborative problem-solving) skills. This was attributed to the absence of a dedicated book or module for the Plant Development Structure course that could facilitate students in improving collaborative problem-solving skills and engaging in enjoyable learning activities. The teaching approaches and instructional materials used did not adequately reflect the stages required to train collaborative problem-solving skills. Consequently, there was a need for instructional materials that could enhance collaborative problem-solving skills and innovation based on Problem-Based Learning (PBL) principles.

The needs analysis results for students in Office A and Office C who had already taken the Plant Development Structure course were conducted through observations aligned with collaborative problem-solving skill indicators. After conducting the needs analysis, the percentage value obtained was 48.29%, categorized as insufficient. The needs analysis for instructors and students also resulted in the design of an instructional material development in the form of an E-Module that is representative and aligned with the students' needs. Based on the needs analysis conducted through interviews with the lecturer responsible for the course, there is a significant deficiency in the coverage of pollination, fertilization, and seed organ development topics. The course on plant developmental structures also lacks more complex modules, and cognitive learning outcomes in this course are still low.

2. Results of Front-End Analysis

The purpose of this stage is to collect accurate data in the field and use it as a basis for determining the solutions to be developed. The data is obtained through several analysis stages, including audience analysis, technology analysis, and task analysis. Observations revealed that assignments were already structured in the form of collaborative problem-solving within small groups; however, the innovation of projects and the essence of collaboration were not yet optimized. Subsequently, critical incident analysis, situational analysis, objective analysis, and media analysis were conducted. In this study, the development of electronic modules (e-modules) based on a website platform was undertaken. A website was chosen as the e-module development platform due to its easy accessibility through smartphones or laptops. Additionally, the data used in the analysis also included extant data analysis. The final analysis pertained to cost analysis, aiming to identify the expenditure aspects needed for the implementation of the research.

Design Stages

The design stage was conducted in August 2022, focusing on the development of instructional materials using a predefined model to support the learning process. During this stage, the initial design of the E-module was generated to enhance students' collaborative problem-solving skills, incorporating specifications tailored to the needs analysis.

Development Stages

The development stage involved creating a storyboard, packaging interface designs, content presentation development, revision or improvement, and product packaging. The E-Module was developed based on the storyboard created in alignment with Learning Outcomes (LO). The interface design included home, introduction, sub-CPMK, table of contents, E-Module usage instructions, practice questions, content, learning activities, evaluation, glossary, and bibliography. The outcome of this stage was instructional material that is valid and ready for implementation to enhance students' collaborative problem-solving skills, along with product validation results.

Table 2. Content Expert Validity Score

No.	Indicators	Total Score	Maximum Score
1.	Relevance of the Content Description to the Course Program Learning Outcomes (CPMK) and Sub-CPMK	35	35
2.	Content Suitability	100	100
3.	Stimulating Curiosity	20	20
4.	Presentation Support	10	10
	TOTAL	165	165

Based on abover table, hence:

$$User\ Validity = \frac{Total\ Empirical\ Score}{Max. Total\ Score} \times 100\%$$
$$= \frac{165}{165} \times 100\%$$
$$= 100\%$$

Based on the table, it can be observed that the material in the E-module on plant developmental structure based on Problem-Based Learning (PBL) with formative assessment is deemed suitable for use in the learning process concerning pollination, fertilization, and the development of seed organs.

Table 3. Media Expert Scoring Result

No.	Indicators	Total Score	Maximum Score
1.	Completeness of Module Components	84	85
2.	Content Feasibility	204	205
3.	Language Feasibility	45	45
	TOTAL	333	335

Based on above table, hence:

$$\text{User Validity} = \frac{Total\ Empirical\ Score}{Total\ skor\ Maksimal} \times 100\%$$
$$= \frac{333}{335} \times 100\%$$
$$= 99.4\%$$

The validation results by the module experts indicate that the E-module on plant developmental structure based on Problem-Based Learning (PBL) with formative assessment is deemed suitable for use in the learning process concerning pollination, fertilization, and the development of seed organs.

Table 4. Validation Results by Field Practitioners

No	Aspect	Score	Value (%)	Criteria
1.	Presentation Components	43	95.5	Highly Valid
2.	Content Suitability	45	100	Highly Valid
3.	Language Suitability	19	95	Highly Valid
4.	Presentation Suitability	14	93.3	Highly Valid
5.	Learning Syntax	139	92.5	Highly Valid

Based on the validation results by field practitioners, the E-module on plant developmental structure based on Problem-Based Learning (PBL) with formative assessment obtained a percentage of 95.26%, categorizing it as highly valid. Therefore, the E-module on plant developmental structure based on PBL with formative assessment for topics related to pollination, fertilization, and the development of seed organs can be considered suitable for implementation in the learning process.

Implementation Stages

This stage involves preparing both instructors and students for the implementation of the developed E-Module. The instructor/model researcher prepares the instructional materials, particularly the developed E-Module. The subjects of this research are students majoring in Biology Education at the University of Malang who are currently taking the Plant Developmental Structure course. The implementation is divided into two classes: the Control Class and the Experimental Class. Class B, with 38 students, serves as the control class, while Class C, with 36 students, serves as the experimental class. The preparation of students in the experimental class involves guiding them to follow the instructions for using the Plant Developmental Structure E-Module during the learning process. Throughout the learning process, observers are deployed, consisting of fellow researchers, specifically master's students. The control class follows the standard learning procedure, implementing the Problem-Based Learning (PBL) teaching model. Additionally, preparations are made for scheduling the implementation, distributing the E-Module instructional media, and addressing any technical preparations required by the students. This research is conducted during the months of November and December in the academic year 2022/2023.

The advantages of the developed e-module include its easy accessibility for students. It provides references in the form of journals, and there is material available to answer post-test questions. The weaknesses of the developed e-module may include a lack of attractiveness and some fonts not matching the background. This issue can be revised. Additionally, the e-module can only be accessed online.

Evaluation Stages

After the implementation, an evaluation is conducted. In this stage, adjustments or revisions are made to the developed E-Module, and the collaborative problem-solving (collaborative problem-solving) skills of the students are analyzed. The assessment of collaborative problem-solving skills is obtained through self-assessment, peer-assessment, and observation. The results of the collaborative problem-solving skills assessment are analyzed using an ANCOVA test, preceded by prerequisite tests consisting of normality and homogeneity tests. The reason for choosing the follow-up ANCOVA in this research is to determine the influence of the e-module on students' collaborative problem-solving skills. Data obtained from the assessment of students' collaborative problem-solving skills include three aspects: self-assessment, peer-assessment, and observation. Therefore, the ANCOVA test can analyze the data derived from the results of this research.

Table 5. Normality and Homogeneity Test of collaborative problem-solving Skills from Self-Assessment

No.	Group	Normality (Kolmogorov Smirnov)	Homogeneity (Levene Test)
1	Control (Non-*E-Module*)	0,200	0,401
2	Experiment (*E-Module*)	0,136	0,401

Table 6. Normality and Homogeneity Test of collaborative problem-solving Skills from Peer-assessment

No.	Group	Normality (Kolmogorov Smirnov)	Homogeneity (Levene Test)
1	Control (Non-*E-Module*)	0,200	0,545
2	Experiment (*E-Module*)	0,200	0,545

Table 7. Normality and Homogeneity Test of collaborative problem-solving Skills from Observation

No.	Group	Normality (Kolmogorov Smirnov)	Homogeneity (Levene Test)
1	Control (Non-*E-Module*)	0,063	0,553
2	Exsperiment (*E-Module*)	0,074	0,553

Table 8. Normality and Homogeneity Test of Overall collaborative problem-solving Skills

No.	Group	Normality (Kolmogorov Smirnov)	Homogeneity (Levene Test)
1	Control (Non-*E-Module*)	0,200	0,081
2	Exsperiment (*E-Module*)	0,052	0,081

Table 9. ANCOVA Test Results of collaborative problem-solving Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13440.188[a]	3	4480.063	578.640	.000
Intercept	1216.265	1	1216.265	157.091	.000
Class	53.799	1	53.799	6.949	.010
Pretest_collaborative problem-solving	.678	1	.678	.088	.768
Class * Pretest_collaborative problem-solving	.746	1	.746	.096	.757
Error	541.968	70	7.742		
Total	390416.587	74			
Corrected Total	13982.156	73			

The ANCOVA analysis of collaborative problem-solving (collaborative problem-solving) skills in the E-Module indicates a significant difference. These results suggest that the developed E-Module has the potential to enhance students' collaborative problem-solving skills, particularly when implemented with the Problem-Based Learning (PBL) teaching model.

Figure 1. Homepage of the Developed E-Module.

Based on the learning outcome of collaborative problem-solving, an improvement in students' collaborative problem-solving can be observed. The improvement of collaborative problem-solving in Off C class, the experimental class, is higher than in Off B class, the control class, in each meeting. Therefore, it can be concluded that the use of the e-module can improve the students' collaborative problem-solving skills. Collaborative Problem Solving is a learning activity in which students work in small groups when studying mathematics to achieve common goals (Albert & Kim, 2013).

Based on a study conducted by Xu *et al.*, (2022), the underdevelopment of engineering students' collaborative problem-solving skills is attributed to the lack of learning media available for them. Through the use of e-modules, collaborative problem-solving skills can be improved, thus facilitating the realization of learning objectives. The findings of this research align with a study conducted by Nerliana Sihombing and Retno Dwi Suyanti (2022), which find that students' problem-solving skills using a collaborative learning-oriented learning cycle model supported by e-modules have a higher reaction rate than the Minimum Completion Criteria (KKM) set at 75.

4. CONCLUSION

Based on the achievement of collaborative problem-solving, it can be observed that there is an improvement in students' collaborative problem-solving skills. Off C class, the experimental class, shows higher improvement in collaborative problem-solving compared to Off B class, the control class, in each meeting. Thus, it can be concluded that the use of the e-module can improve the students' collaborative problem-solving skills.

Based on the validity test, the score from media experts is 99.4% and from content experts is 97.6%. Thus, it can be said that the e-module content is highly valid both in terms of content and media, allowing the e-module to be used without any revisions. Based on the practicality test, the score is 95,26%. Therefore, it can be said that the e-module content is highly practical, allowing the e-module to be used with revisions.

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