Bioedukasi
Jurnal Biologi dan Pembelajarannya
Vol. 22 No 2, June 2024, page 318-326
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v22i2.46624
jurnal.unej.ac.id/index.php/BIOED

Development of E-Module for Plant Physiology Courses Based on Problem Based Learning to Increase Student's Critical Thinking Skills on Nutrition, Transportation and Photosynthesis

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Article Info
Article history:
Received February 10, 2024
Revised June 18, 2024
Accepted June 21, 2024

Keywords:
Critical Thinking Skills
E-module
Nutrient Transport
Photosynthesis
Problem Based Learning

ABSTRACT
This development research aims to develop, test the validation, practicality and effectiveness of e-modules in improving students' critical thinking skills for plant physiology courses. The material used in the implementation stage focuses on the material of Nutrition and Nutrient Transport in Plants. The method used Research and Development (R&D) development using the Lee & Owens model development design. The research was conducted at the State University of Malang on students majoring in biology education semester 3 totaling 33 experimental class students and 33 control class students. The results obtained from material validation are 100% with very valid criteria. Furthermore, media validation is 95.47% with very valid criteria, practitioner validation with a percentage value of 97.27% with very valid criteria. Practicality test averaged 96% including very practical criteria. The effectiveness test was obtained through the e-module implementation stage with the Nonrandomized Control-Group Pretest-Posttest Design research design using the N-gain score calculation which was 0.70 with high criteria on experimental class. 0.29 for control class which was on low criteria. Based on the test results that have been carried out, the development of e-modules based on Problem-based learning in critical thinking skills is said to be valid, practical, and effective in improving students' critical thinking skills.

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1. INTRODUCTION

Education plays a role in developing personality and intelligence as well as the skills needed to develop self-potential (Agustina & Astuti, 2020). Education has challenges in building community skills in the global era in the 21st century. These challenges also provide opportunities to encourage the creation of new innovations in the field of education, one of which is in the field of information technology or Information and Communication (ICT). mainly used as a tool to support efforts to develop skills in the field of education in the learning process (Van Laar *et al.*, 2020). According to Agustina & Astuti (2020), developments in the field of information and communication technology also affect progress in innovation in developing teaching materials, including electronic module (e-module). E-modules are expected to assist students in obtaining information related to the material being studied and according to the needs of students (Yetti & Ahyanuardi, 2020).

Based on the implementation in the field, the use of modules as teaching materials has not been used optimally. From the results of the needs analysis conducted on 02 April 2023 on the lecturer teaching the Plant Physiology course at the Department of Biology Education, State University of Malang, it shows that the module is not fully used by lecturers as a medium for learning Plant Physiology. Filling out the needs analysis questionnaire was also carried out by students who had taken the Plant Physiology course before. As many as 90.6% of students need electronic-based teaching materials in supporting the learning process on plant physiology material.

The creation of learning that is able to build two-way interactions between students and lecturers has the potential to encourage the achievement of learning objectives in the 21st century (Yetti & Ahyanuardi, 2020). So that the skills needed to prepare students in the field of education and the work industry are critical thinking skills (Pahrudin *et al.*, 2021). Students' critical thinking skills are needed in understanding the material and supporting

the understanding of material with a higher level of reasoning (Suarsana, 2019). In reality, in certain materials, the level of critical thinking skills of students is still relatively low.

Based on the results of the needs analysis of students conducted on 02 April 2023, it was reported that the obstacles found during learning were in determining appropriate teaching methods and materials. This is supported by the results of the initial test of critical thinking skills of undergraduate Biology students at State University of Malang who took the plant physiology course in the low category with an average score of 53%. Strategies and the use of methods and teaching materials are needed to support the creation of appropriate learning activities. Not only the right teaching materials, but a learning model is also needed that can influence learning activities so that learning objectives can be achieved as expected (Anggur *et al.,* 2021). In this case, the learning model used is based on Problem Based Learning (PBL). Research on the use of e-modules based on Problem Based Learning shows that there are differences in critical thinking skills between groups of students who use e-module assistance (experimental class) and those who do not use e-module (control class) (Nurhidayat, 2021). Based on this statement, it is known that research is needed by developing independent learning resources in the form of e-modules based on Problem Based Learning.

2. RESEARCH METHOD

The type of research used is Research and Development (R&D) with the Lee & Owens development model. The stages of the Lee & Owens development model are presented in Figure 1.

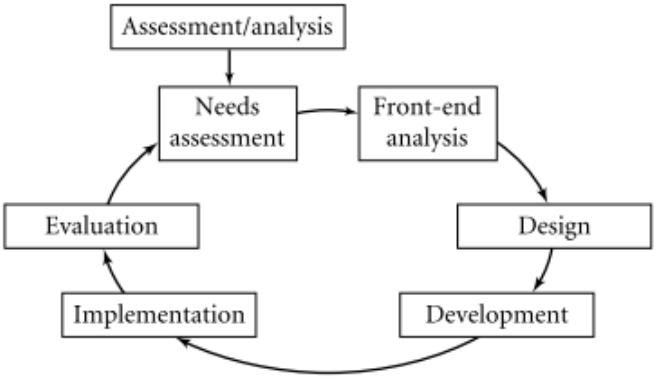

Figure 1. Stages of the Lee & Owens Model
Source: (Lee & Owens, 2004:3)

The data collection techniques used consisted of validation Questionnaires, critical thinking skills tests, and documentation. The data analyzed were the validity, practicality, and effectiveness of the e-module. The research design used is Nonrandomized Control-Group Pretest-Posttest Design and uses the calculation of Normalized Gain (N-Gain). The research implementation design with Nonrandomized Control-Group pretest-Posttest Design is presented in Table 1.

Table 1. Nonrandomized Control-Group pretest-Posttest Research Design

Group	**Pertest**	**Treatment**	**Post test**
Experiment	O_1	X_1	O_2
Control	O_3	X_2	O_4

Source: Leedy and Ormrod (2021:233)

a. E-module Validity

E-module validation uses a Likert Scale with the formula (Akbar, 2017:82):

$$\mathbf{V} = \frac{\boldsymbol{TSe}}{\mathbf{TSh}} \times \mathbf{100}\%$$

Description:
V : Percentage value of validity
TS-e: The number of respondents' answer scores in one question item
TSh : Number of ideal scores in one item
The criteria for the validity of the e-module are presented in Table 2.

Table 2. The criteria for the validity of the e-module

Percentage (%)	Qualification	Description
85,01-100	Perfectly Valid	E-module is used without revision
70,01-85,00	Moderately Valid	E-module is used with little revision
50,01-70,00	Less Valid	E-module is not recommended because it needs major revisions
01,00-50,00	Invalid	E-module cannot be used

Source: Akbar (2013:41)

b. Practicality of E-module

The practicality of e-module can be seen from the results of student responses that can operate easily (Akbar, 2017: 82). The following formula is used in calculating the practicality of e-module.

$$\textbf{V-pg} = \frac{TSe}{\text{TSh}} \times 100\%$$

Description:
V-pg: user validation
Tse: total empirical score of validators
TSh: maximum expected score

The results obtained were adjusted to the e-module practicality criteria presented in Table 3.

Table 3. Guidelines for the Validity of Data Analysis in Percentages

Persentage (%)	Qualification	Description
81,00-100,00	Very Practical	E-module is used without revision
61,00-80,00	Practical	E-module is used with little revision
41,00-60,00	Less Practical	E-module is not recommended because it needs major revisions
21,00-40,00	Not Practical	E-module cannot be used
00,00-20,00	Very Impractical	E-module cannot be used

Source: Akbar (2013:42)

c.Effectiveness *E-module*

The effectiveness of the E-module is done with the N-gain score test. This test can provide an overview of the increase in pretest and posttest results between before and after the application of a treatment. The effectiveness of the e-module can be calculated with the following formula.

$$\textbf{Normalized Gain (g)} = \frac{\textbf{posttest score} - \textbf{pretst score}}{\textbf{maximum score} - \textbf{pretest score}}$$

The results obtained are adjusted to the e-module effectiveness category presented in Table 4.

Table 4. N-Gain Level Categories

Value	Category
$g > 0,7$	High Effectiveness
$0,3 \leq g \leq 0,7$	Medium Effectiveness
$g \leq 0,3$	Low Effectiveness

Source: Hake, R (1999:1)

3. RESULT AND DISCUSSION

A. RESULT

E-Module Development

The development of e-modules aims to improve students' critical thinking skills. The e-module produced in this research is on the material of Nutrition and Nutrient Transport in the Plant Physiology course.

1) Analysis

The analysis stage is carried out based on the needs analysis stage by filling out a questionnaire to students of the UM Biology Department on February 13, 2023. The results of the needs analysis found that 90.6% of students need electronic-based teaching materials in supporting the learning process on Plant Physiology material. The obstacles found during learning are in determining appropriate teaching methods and materials.

2) Design
This stage focuses on the results of the needs analysis which is used as a basis for developing e-modules. The development implementation is designed to start in July 2023 until September 2023. Design results of the E-module that has been developed, presented in table 5.

Table 5. Details of E-Module Design

E-module section	No.	E-module sub section	Content
Introduction	1.	Cover *e-module*	Title, course, author's name, illustration image, university logo
	2.	Introduction	Preface that contains thanks from the author, the purpose and benefits of developing e-modules
	3.	Table of Contents	Table of contents about the contents of the e-module
	4.	List of Images	List of images included in the e-module
	5.	Table List	List of tables included in the e-module
	6.	Menu	List of content components contained in the e-module
	7.	Instructions for use	Instructions for using the e-module for users
	8.	CPMK Indicator	Indicators of learning outcomes of courses that use e-modules
Content	1.	Learning activities	Topic material description
	2.	Student worksheet	Student activities based on PBL syntax stages
	3.	Did you know	Additional information in the form of a brief summary to strengthen student knowledge
	4.	Glossary	explanation of abbreviations or definitions of foreign words used in the e-module
Conclusion	1.	Evaluation	Self-reflection and understanding after using the e-module
	2.	Reference List	List of references used in the preparation of the e-module
	3.	Author Profile	Information about the authors of the e-module

3) Development
The media developed in this research is in the form of electronic modules or e-module on Nutrition and Nutrient Transport in Plants. E-module validation is carried out by expert validators to determine the validity of the media to be developed. Validation is done by filling out a validation sheet assessment questionnaire. Expert validators include material expert validators, media experts and field validators by biology education practitioners. Revisions are made based on the input or suggestions given by each expert validator. After being declared valid and feasible to be tested without revision, the media is ready for further implementation.
4) Implementation
The e-module, which has been determined to be valid and feasible for testing, is then implemented on 3rd semester students who are taking the Plant Physiology course at the Department of Biology at the State University of Malang. This activity was carried out in two classes (experimental and control) totaling 66 students on 05, September 2023 to 06 October 2023 for 3x meetings.
5) Evaluation
The evaluation stage is carried out by collecting data on the results of validation and field trials. Validation of media, materials and learning devices by biology education practitioners. The data is evaluated as a consideration in determining the validity and can be used in the trial of the e-module that has been developed.

Presentation of Data

The results of the validation and field trial data are presented as follows:
1) Validation
Below are the results of the validation data analysis of the e-module, namely material validation, media validation, and validation by biology education practitioners.
a) Material Validation
Material validation was carried out by a material expert validator, Dr. Husamah, M.Pd. on 02 September 2023. This validation was carried out to provide an assessment of the material content presented in the e-module. The results of the assessment by the material expert validator are presented in Table 6.

Table 6. Assessment Results by Material Expert Validators

No.	Assessment Aspects	Number of aspects	Total Score	Maximum Score	Validity	Category
1.	Title	2	10	10	100%	Perfectly Valid
2.	Example or illustration	3	15	15	100%	Perfectly Valid
3.	Image/photo/video	3	15	15	100%	Perfectly Valid
4.	Language	3	15	15	100%	Perfectly Valid
5.	Depth / breadth of material	2	10	10	100%	Perfectly Valid
6.	Correctness of Material Concepts	3	15	15	100%	Perfectly Valid
7.	The currency of the material	3	15	15	100%	Perfectly Valid
8.	Contextuality of the material	3	15	15	100%	Perfectly Valid
Total					800	Perfectly Valid
Average					100%	Perfectly Valid

The results of material validation based on Table 6 are worth 100% with a very valid category or can be tested. This shows that the material contained in the e-module is considered very valid or can be tested without revision. Comments and suggestions given by material expert validators, namely revisions/improvements are in accordance with what has been suggested and the e-module is suitable for use.

b) Media Validation

Media validation was carried out by a media expert validator, Prof. Dr. Dedi Kuswandi, M.Pd on 01 October 2023. This validation was carried out to provide an assessment of the media content on the e-module. The results of the assessment by the material expert validator are presented in Table 7.

Table 7. Assessment Results by Media Expert Validators

No.	Assessment Aspects	Number of aspects	Total Score	Maximum Score	Validity	Category
1.	Cover Design	6	29	30	96,66%	Perfectly Valid
2.	Content Design	14	66	70	94,28%	Perfectly Valid
Total					190.94	Perfectly Valid
Average					95.47 %	Perfectly Valid

The media validation results obtained based on Table 7 are 95.47% with a very valid category. This shows that the media in the form of e-module is considered very valid or can be tested without revision. The comments and suggestions of media expert validators on e-module media are good, complete and harmonious.

c) Learning Device Validation

Validation of teaching devices or materials to be used is first validated by field expert validators or biology education practitioners Dr. Husamah, S.Pd., M.Pd. On 02 September 2023. The results of the assessment by expert validators of biology education practitioners are presented in Table 8.

Table 8. Biology Education Practitioner Validation Results

No.	Assessment Aspects	Number of aspects	Total Score	Maximum Score	Validity	Category
1.	Completeness of Content	4	20	20	100%	Perfectly Valid
2.	Characteristics of e-module	2	10	10	100%	Perfectly Valid
3.	Language	4	19	20	95,00%	Perfectly Valid
4.	Presentation	2	10	10	100%	Perfectly Valid
5.	Material	3	14	15	93,33%	Perfectly Valid
6.	Graphics	3	14	15	93,33%	Perfectly Valid
7.	PBL Learning Syntax	4	20	20	100%	Perfectly Valid
Total					681	Perfectly Valid
Average					97.29%	Perfectly Valid

Based on the results of validation by field expert validators in Table 8, the results show that the average score of all aspects obtained is 97.29% with a very valid category and can be tested.

2) Practicality

The practicality test was carried out in two stages, the first stage was carried out after the validation of the e-module, this stage was carried out on students who had taken the plant physiology course, including one to one trial, small group trial, field trial and conduct pilot test. The second stage is carried out after implementation on students who are taking plant physiology courses. The summary of the e-module practicality test results is presented in Table 9.

Table 9. Results of the E-Module Practicality Test Assessment

No.	Stages of Practicality Test	Average Score (%)	Category
1.	*One To One Trial*	97,76	Highly Practical
2.	*Small Group Trial*	99	Highly Practical
3.	*Field Trial*	94,25	Highly Practical
4.	*Conduct Pilot Test*	98,23	Highly Practical
5.	Implementation Class Practicality Test	96	Highly Practical

The practicality test based on Table 9 obtained a percentage value of 98.3%. These results indicate that the e-module developed is included in the very practical category and can be used by students.

3) Effectiveness

The effectiveness test was analyzed using the N-Gain score test on pretest and posttest scores to measure the effectiveness of the e-module in improving students' critical thinking skills. pretest and posttest were given to students who were taking plant physiology courses in experimental and control classes. The results obtained were then tested for normality. The results of the N-gain score test on student pretest and posttest scores are presented in Table 10.

Table 10. N-Gain Score Test Results of Students' Critical Thinking Skills

Indicator	*Apply*	*Evaluate*	*Use Data to Develop Critical Insight*	*Analyze*	*Synthesize*	Average
Experiment	0,93	0,72	0,81	0,57	0,47	0,70
Control	0,17	0,32	0,23	0,37	0,37	0,29

Based on the results of the N-Gain test in Table 10, the average score in the experimental class is 0.70, which means that the effectiveness of the e-module is in the high category. Each indicator of students' critical thinking skills, the highest average is in the apply indicator with a value of 0.92 which is included in the high effectiveness category.

Then according to the pretest and posttest scores, normality and homogeneity tests were carried out which are presented in Table 11.

Table 11. Normality and Homogeneity Test of Students' Critical Thinking Skills

Test Value	Normality		Homogeneity	
	Significant	Description	Significant	Description
Pretest	0,151	Normal	0,748	Homogen
Posttest	0,200		0,504	

Based on Table 11, the results of the normality and homogeneity tests of the pretest-posttest of students' critical thinking skills obtained significance results of 0.151 and 0.200 which means the data is normally distributed. and 0.748 and 0.504 which means the data is homogeneous (significance> 0.05).

Furthermore, hypothesis testing was carried out on students' critical thinking skills. The results of hypothesis testing are presented in Table 12.

Table 12: Hypothesis Test Results of Students' Critical Thinking Skills

No	Class	Pretest Average	Posttest Average	Significant	Interpretation
1.	Experiment	53.18	79.09	0,014	H0 rejected
2.	Control	47.87	52.27		

Based on Table 12. Hypothesis Test Results obtained a significance value of 0.014 <0.05, the value is smaller than the value of 0.05 with the assumption that H0 is rejected H1 is accepted. This shows that there is an effect of learning by using e-module plant physiology based on Problem Based Learning on students' critical thinking skills.

B. DISCUSSION

The product developed in this media development is an E-Module of Plant Physiology based on Problem Based Learning. The material used is Nutrition and Nutrient Transport in Plants in the Plant Physiology course at State University of Malang. The validation carried out on the e-module is material validation, media validation and validation of learning devices by field practitioners. The developed e-module has also been tested for practicality using a student response questionnaire sheet. The e-module is implemented in learning to improve students' critical thinking skills.

The validity of the Problem Based Learning-based Plant Physiology E-Module

Teaching materials that are developed, before being implemented for students, need to be validated beforehand. Validation aims to produce valid teaching materials (Silalahi, et al., 2020). Validation of the e-module was carried out by several experts, namely material validators, media validators and field practitioner validators. The e-module that has been validated is then calculated the average value obtained. Expert validators first provide suggestions and input for the e-module to further guide in improving the e-module. The e-module product has an organized page display with a proportional font size and images or illustrations that are adjusted to the material content of the e-module (Nora et al., 2022). Illustrations or images that are loaded can also support the clarity of the material and the e-module is expected to initiate student effectiveness in learning (Malik., 2021).

The result of the percentage of material expert validators is 100%, indicating that the material contained in the e-module is considered very valid and can be tested. The results of validation by media experts including the category very valid and can be implemented is with a percentage value of 95.47%. While the percentage value obtained based on device validation by field expert validators or biology education is 97.27% in the very valid category. Learning modules need to meet valid standards validated by expert validators according to their respective fields. The level of validity aims to make the e-module feasible to use in learning (Sukir et al., 2019).

Practicality of Plant Physiology E-Module Based on Problem Based Learning

The requirement that must be met by the e-module as teaching material is practicality. The practicality test on the e-module aims to determine the level of practicality of using the e-module in learning based on the results of the validation carried out. The practicality validation of this e-module is based on several aspects of assessment, namely completeness of content, characteristics, language, presentation, material and graphic aspects. Teaching materials are said to be practical if they can support learning activities. E-Module contains content as a means of supporting learning in the form of materials, methods, problems, reading materials that aim to train students' independence in learning, encourage students to be actively involved in learning and be able to solve problems based on their abilities or ideas (Nurhidayat, 2021). The practicality validation results from the validator obtained an average value of 98.3% in the very practical category, which indicates that the e-module developed has met the practicality criteria and is suitable for use by students.

Effectiveness of Problem Based Learning-based Plant Physiology E-Module

The e-module effectiveness test was conducted to determine the level of effectiveness of using the e-module in improving students' critical thinking skills. The effectiveness of using this e-module is based on pretest and posttest scores using the N-Gain score. Based on the results of data analysis using the N-Gain score test, the average result is 0.69 which indicates that the average is in the medium category or medium. While the further test obtained a significance value of 0.014 <0.05 which indicates that there is a significant difference in the results of the pretest and posttest on students' critical thinking skills.

The use of PBL-based e-modules can optimize students' critical thinking skills through the problem-solving process. According to Andriyani (2020), the use of problem-based e-modules can optimize students' Please check the writing, use of English and the template still has lots of error sigh Order Thinking Skills (HOTS) through the ability to solve and resolve problems that arise in everyday life. The PBL-based Plant Physiology E-Module developed here presents problems related to everyday life. The problems are presented on the Student Worksheet (LKM) and can be accessed easily by students.

Critical thinking skills combine two main processes that are considered important, namely the skills of understanding and testing a process (Zo'ubi, 2021). Therefore, this developed e-module contains issues that are tailored to learning materials and are closely related to everyday life. Learning activities based on problems that

occur in the surrounding environment can encourage knowledge and understanding of concepts through their critical thinking skills and problem solving (Hart et al., 2021). The E-Module developed and declared valid, practical and effective is expected to help students to improve the quality of learning in class and independent learning so as to improve students' higher order thinking skills, especially in the Plant Physiology course.

4. CONCLUSION

Based on the results of the validity test of the problem-based learning-based plant physiology E-module by material expert validators, learning media experts and field practitioner experts, the material validation value is 100%, media validation is 95.47% and biology practitioner validation is 97.27%. The validation results show a very valid category and can be used in learning in the Plant Physiology course. The results of the practicality test obtained an average score of 96% classified as a very practical category. Based on the results of the validity and practicality tests, it can be concluded that the e-module developed has a high level of validity and is easy to use in learning plant physiology. The results of the e-module effectiveness test on students' critical thinking skills based on the N-Gain score test obtained an average result of 0.70 which indicates that the effectiveness of using e-modules in learning is in the high category. The results of the feasibility test in the form of normality and homogeneity tests get significance> 0.05 and it is said that the data is normally distributed and homogeneous. Furthermore, hypothesis testing of critical thinking skills between experimental and control classes showed significance <0.014, indicating that there was an effect of learning by using e-modules on students' critical thinking skills.

5. ACKNOWLEDGEMENT

I would like to express my sincere thanks to Prof. Dr. H. Abdul Gofur, M.Sc. and Dr. Balqis, S.Pd., M.Si. for their extraordinary contribution in writing my journal article entitled "Development of a PBL-Based Transport and Exchange Process E-Module to Improve High School Students' Critical Thinking Skills." Their presence and involvement in reviewing this manuscript has added significant value to the quality of the writing. I really appreciate the time and dedication they took to provide valuable feedback and input. The constructive criticism and suggestions provided not only enriched the content of the article, but also helped me to refine and improve the methodology and arguments presented. Thank you for the insightful insight and breadth of knowledge they have shared. This collaboration has been a valuable experience for me, and I hope that the results of this collaboration can make a positive contribution to the development of science and education.

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