RESEARCH ARTICLE

Development of a flipped classroom-based e-module to improve problem-solving abilities and learning independence of high school students

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Article history
Received: 3 February 2024
Revised: 6 June 2024
Accepted: 13 June 2024
Published: 6 July 2024

10.22219/jpbi.v10i2.32183

p-ISSN: 2442-3750
e-ISSN: 2537-6204

How to cite:

Ayunda, A., D., Hasanah, H., & Ariyanti, N., A. (2024). Development of a flipped classroom-based e-module to improve problem-solving abilities and learning independence of high school students. *JPBI (Jurnal Pendidikan Biologi Indonesia), 10 (2)*, 453-466. https://doi.org/10.22219/jpbi.v10i2.32183

Abstract: Non-optimal use of teaching materials and learning techniques impacts students' low skills, especially problem-solving abilities and learning independence. The study aims to develop a flipped classroom-based e-module that is feasible, practical, and effective in improving students' problem-solving skills and learning independence. This research and development use the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. Next, the field trial design uses a quasi-experimental method with a non-equivalent control group design, which means using two groups, namely experimental and control. The research subjects were students from SMA N 1 Seyegan who were selected using a cluster random sampling technique with a lottery system. Through drawing, class XI MIPA 3 was obtained as the control class and XI MIPA 4 as the experimental class, each consisting of 34 students. The data collection instruments used were product assessment questionnaires from material experts, media experts, biology teachers, and students, as well as independence questionnaires and problem-solving ability test instruments. Hypothesis testing was carried out using multivariate testing. The research results show that the e-module is considered suitable for use in learning based on material and media experts, is considered practical in its use according to the assessment of teachers and students, and is effective in improving problem-solving abilities and learning independence.

Keywords: e-module; flipped classroom; learning independence; problem-solving abilities

Introduction

The development of information technology has influenced the world of education (Okrul et al., 2020). Vidianti & Qonita, (2022) stated that this is reflected in the use of facilities in schools, such as computer equipment, LCD projectors, internet connections, computer-based learning media, electronic teaching materials, Android devices, and so on. Students will obtain education through the learning process, both formal and non-formal. To achieve optimal results, it is important to ensure quality in the teaching and learning process (Manalu et al., 2022).

Current education needs to be adapted to the demands of the 21st century, where innovation skills, understanding of information and technology, and life skills are a must for individuals (Haka et al., 2021). One of the ways that innovative learning can be created is by using technology. Technology that is used intensively by students can be used as a tool in learning which is expected to increase student understanding and retention (Mustofa et al., 2019) and build important skills such as problem-solving, independent learning, critical thinking, collaboration, and communication (Indriani & Sakti, 2022; Prawitasari et al., 2021; Saputra & Gunawan, 2021).

In line with this Indriani & Sakti, (2022) said that problem-solving ability is one of the skills that students must have to face the industrial revolution 4.0 of the 21st century to be able to participate in building a socio-economic order that is aware of scientific knowledge as befits world citizens in the 21st century who are competitive in this era globalization. Problem-solving ability is the skill to identify and understand a problem, plan an effective strategy, organize information, make the right decisions, and implement plans to solve the problems faced (Wulandari et al., 2021). Problem-solving abilities can train students how to think critically, carefully, analytically, and creatively so that they can produce a generation that has high analytical power.

However, the reality on the ground is not as expected. The low problem-solving abilities of students were also experienced by researchers in class XI of SMA Negeri 1 Seyegan. This is known from the results of preliminary research that has been carried out, namely using problem-solving ability test questions which show an average score of 45.6%, which means it is still low. This is also reinforced by the results of the PISA survey Haka et al., (2021) that the problem-solving abilities of Indonesian students are still low, both in the content dimension and the cognitive dimension, namely out of 100 students, 73 of them at level 1 which is the lowest level, meaning only 27 students can solve problems. This condition illustrates that students' problem-solving abilities need to be improved.

Apart from emphasizing cognitive aspects such as problem-solving abilities, affective aspects are also very important to pay attention to in learning because they influence student learning outcomes, one of which is learning independence. Students need to have an attitude of self-initiative in learning, not depend on others, be self-disciplined, be responsible for themselves, and believe in their abilities. Where this is an indicator of students' learning independence (Puspitasari, 2019). Independent learning is very important and must be a concern in the world of education (Lovez et al., 2023). This is in line with what was said by Effendi et al., (2018) namely, learning independence is a critical element in students' success during the learning process, and therefore, an independent attitude is very essential for students. Based on the results of observations at SMA N 1 Seyegan, students' learning independence is still relatively low. This low level of learning independence is assessed from the results of the needs questionnaire and biology teacher interviews which state that students' learning activities still appear passive and only listen to the teacher's lectures, so this causes students to always depend on the teacher's orders. This was also said by Gea et al, (2022), in their research, the majority of students were not yet independent in learning, during learning it was seen that students were still dependent on their friends and did not have a confident attitude in expressing their opinions or asking questions.

Responding to problems that occur in the learning process, researchers focus on improving problem-solving abilities and learning independence. These two abilities are one of the most important foundations that students must have to face the challenges of the 21st century (Fadillah et al., 2022). Efforts that can be made include improving the quality of the current learning process by using technology in appropriate teaching materials, strategies, and learning models.

By using technology in learning, e-modules become one of the learning media that can be used (Wulandari & Nana, 2021). Namely, learning independence is a critical element in students' success during the learning process, and therefore, an independent attitude is very essential for students. E-Module is digital learning material that has been designed systematically and logically and can be accessed independently by students (Puspitasari, 2019). According to Arnila et al., (2021) e-modules are designed systematically according to the curriculum, arranged in the form of the smallest learning units that can be studied independently without time restrictions. This aims to ensure that students can better master the competencies being taught. Using technology through e-modules that combine technology and learning can provide new experiences in teaching and learning activities because they are interactive and considered more interesting (Hidayati Azkiya et al., 2022; Putri & Eilmelda, 2022; Azzilani & Tutik, 2021). Several studies have examined the benefits or effectiveness of e-modules to improve learning abilities. Many studies on e-modules have found that e-modules can improve critical thinking skills, and learning independence and attract students' attention to interact and focus on learning (Nugraha, 2018; Solomon et al., 2019; Latifah et al., 2020).

Based on its function and benefits, the e-module is expected to provide a learning experience in building students' knowledge and skills. Success in the learning process is influenced by many factors, both internal and external. Apart from the teaching materials used, other factors that influence learning success include the strategies and learning models used. The selection and use of good learning strategies and models is one of the important factors that support the learning process (Panjaitan et al, 2022). One strategy that can be combined with e-module teaching materials is the flipped classroom approach (Azzilani & Tutik, 2021). The flipped classroom is a blended learning variation approach that encourages students to think critically and think creatively (Al-Khateeb, 2018). In a flipped classroom, material delivery is carried out before class, while assignments, active discussions, and material reinforcement are carried out in class. This is by the statement Cahyaningrum & Jaenudin, (2021), that learning using e-modules based on flipped classrooms is effectively applied in learning because students will understand the concepts of the material earlier, thereby training students to learn independently.

Apart from choosing the right strategy, choosing a learning model that can improve problem-solving abilities is by using a problem-based learning (PBL) model. The problem-based learning model is a learning model that uses the context of problems in everyday life so that students can develop problem-solving skills to gain knowledge and concepts from the material (Andhini et al, 2023). According to research (Hidayatulloh et al., 2020). The flipped classroom approach combined with the Problem-Based Learning model can significantly improve learning achievement, motivation, and learning outcomes.

Based on the explanation above, to improve problem-solving abilities and learning independence, there is a need for innovative teaching materials according to student's needs. With the teaching materials, learning strategies, and learning models used, it is hoped that they will be able to become a bridge for students to improve their problem-solving abilities and learning independence. This research aims to develop a flipped classroom-based e-module that is feasible, practical, and effective for improving the problem-solving abilities and learning independence of class XI high school students.

Method

This research uses research and development methods with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The selection of the ADDIE model is based on its advantages, namely the existence of an evaluation stage at each stage so that it can reduce existing deficiencies in the product and also the hope is that a product that is valid, feasible, practical, effective and can help deal with problems that arise can be obtained (Puspasari, 2019). The reason for choosing the ADDIE model is that the research procedures for developing this model are more rational and more complete (Nababan, 2020). According to Sugiyono (2015) the five stages of ADDIE can be seen in Figure 1.

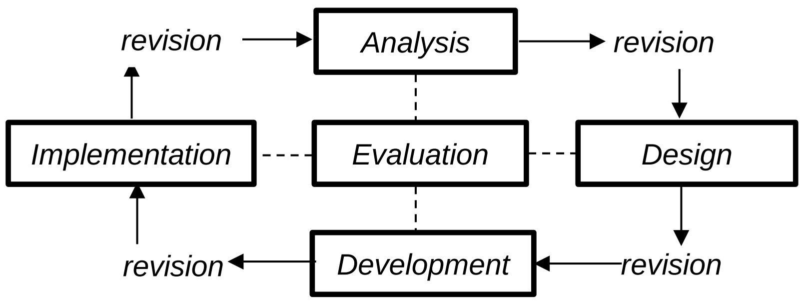


Figure 1. Stages of the ADDIE Development Model

At the Analysis stage, namely analyzing the needs of teachers and students, analyzing the curriculum, and analyzing teaching materials. This analysis stage is carried out to determine the urgency or problems that occur in the field during learning. The design stage carried out is the selection of teaching materials and initial design, such as creating a design for the e-module structural framework in the form of a flowchart, preparing materials, preparing assessment instruments and learning tools as well and preparing the design or learning stages using a flipped classroom-based e-module. At this stage, references are also collected which will be used in developing the e-module. The Development stage is developing the e-module according to the results of the design that has been carried out and then validating it with one media expert, one material expert, one biology teacher, and thirty students. After validation, revisions are carried out and then proceed to the implementation stage. The Implementation stage is conducting field trials to determine the effectiveness of the e-module. The last one is the Evaluation stage, at this stage there are two evaluations, namely evaluation which are applied in four stages, namely analysis, design, development, and implementation, and overall evaluation.
The product trial design in this research involved two trial stages, namely limited trials and field trials. Limited trials focused on students who had taken part in learning about movement systems. Student responses during limited trials are analyzed and used as a basis for making revisions to the product which is then tested more widely in field trials. The field trial design uses a quasi-experimental method with a non-equivalent control group design, which means there are two groups, namely the experimental group and the control group. Trial subjects were taken using a cluster random sampling technique. Sampling was carried out randomly using a lottery system. Based on the drawing, it was found that the subjects in the limited trials were 35 students and the field trials were 68 students, namely class XI MIPA 3 as the control class and XI MIPA 4 as the experimental class with each class totaling 34 students. The instruments used in this research are questionnaires, observation sheets, interview sheets, and test instruments in the form of essay questions to measure problem-solving abilities. The test instrument has passed the validation stage by experts and limited trials before being used in field trials. The data collection techniques used were observation, interviews, questionnaires, and tests. To determine the feasibility of a flipped classroom-based e-module, the data analyzed was validated by material experts and media experts. To determine the practicality of the flipped classroom-based e-module, the data analyzed were the results of biology teacher validation and student responses. The results of the scores from experts and students are then calculated on average and then interpreted according to the criteria for assessing the feasibility and practicality of the product which can be seen in Table 1.

Table 1. Criteria for assessing product feasibility and practicality

Formula	Score	Criteria
$X > (X_1 + 1{,}8\ Sbi)$	A	Very Good
$(X_1 + 0.6\ Sbi) < X \leq (X_1 + 1{,}8\ Sbi)$	B	Good
$(X_1 - 0.6\ Sbi) < X \leq (X_1 + 0{,}6\ Sbi)$	C	Enough
$(X_1 - 1{,}8\ Sbi) < X \leq (X_1 - 0{,}6\ Sbi)$	D	Not Enough
$X \leq (\bar{X}_1 - 1{,}8\ Sbi)$	E	Very Less

Information:
X : Empirical Score
$\bar{X}_1$: Ideal Average (½ (Maximum Score + Minimum Score)
Sbi : Ideal Standard Deviation
= (1/2) (1/3) (ideal highest score – lowest score ideal)
Score Max Ideal: ∑ criteria items X highest score
Score Min Ideal: ∑ criteria items X lowest score

Effectiveness analysis techniques start from learning implementation analysis, problem-solving analysis, and learning independence analysis. Analysis of problem-solving and learning independence was carried out using the Normalized Gain Score (N-Gain). The use of the N-Gain score can illustrate the extent of the role of the flipped classroom-based e-module in movement system material to improve students' problem-solving abilities and learning independence. The following is the normalized N-Gain Score, in Formula 1.

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score} \quad (1)$$

The N-gain score obtained is then interpreted concerning the criteria listed in Table 2, to evaluate the increase in students' problem-solving abilities and learning independence.

Table 2. Interpretation of Criteria *N-Gain*

Scoring Intervals	Category
$g > 0.71$	High
$0.31 < g \leq 0.70$	Medium
$g \leq 0.30$	Low

After carrying out the N-Gain test, the next step involves a Prerequisite Test to determine whether the collected data will be processed using parametric or nonparametric statistics. This prerequisite test involves analysis of normality, homogeneity, homogeneity of the variance-covariance matrix, and multicollinearity tests. If the prerequisite tests are met, then proceed with hypothesis testing using a multivariate test to assess the effect of the e-module on students' problem-solving abilities and learning independence.

Results and Discussion

The result of this development research is a flipped classroom-based e-module that is effective in improving students' problem-solving abilities and learning independence. This e-module can be used independently, providing flexibility in time and place. This research applies a learning activity design by adopting a flipped classroom approach and a problem-based learning (PBL) learning model. The process of developing an e-module based on a flipped classroom on movement system material follows the ADDIE model which includes 5 stages, namely analysis, design, development, implementation, and evaluation.

Analysis

The analysis stage is the initial phase carried out by researchers, where this activity involves collecting information related to the challenges faced by teachers and students to support the learning process. Analysis at this stage includes interviews with teachers, curriculum analysis, and student evaluation. From the results of this analysis, it was identified that inappropriate use of teaching materials and learning techniques was the cause of students' lack of skills. Based on the results of the student needs questionnaire, it was revealed that they expect teaching materials that are more interactive and can be accessed via smartphone. Curriculum analysis shows that competency achievement involves KD 3.5 namely analyzing the relationship between the structure of tissues that make up organs in the movement system about bioprocesses and functional disorders that may occur in the human movement system, and KD 4.10 namely presenting work on the use of technology in overcoming movement system disorders through study of literature. The movement system material is considered difficult by students because many biological terms are difficult to understand, a finding that is also highlighted in previous research, namely research conducted by Adela et al., (2022) that the material regarding the human movement system is conceptual and requires a lot of memorization, accompanied by a lack of representation of real objects that can be explained by the teacher. Apart from that, this material also has many technical terms, such as the names of bones, muscles, joints, and related disorders. Therefore, we need interesting teaching materials that can present pictures clearly and are equipped with interesting videos to help students understand the material comprehensively.

Design

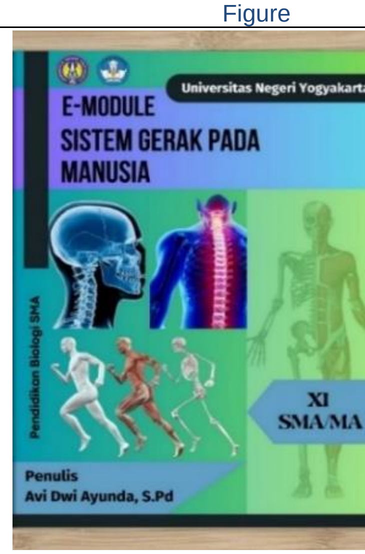
At the design stage, the activities carried out are selecting teaching materials according to the results of the analysis and making an initial design starting from the e-module structure framework, material preparation plans, instruments, learning tools, and learning stages. The choice of teaching materials in this research is an e-module based on a flipped classroom which can be accessed using a smartphone and laptop/computer. According to research conducted by Suryani and Sandika, (2022) Interactive e-modules equipped with images, videos, and audio can be used as an alternative learning method where students can understand and improve their understanding independently.

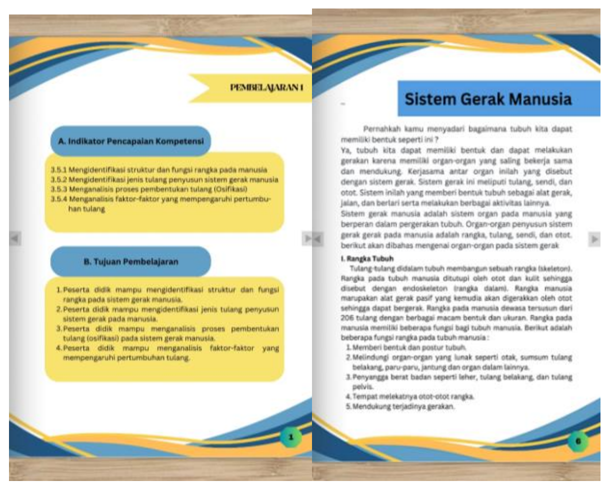
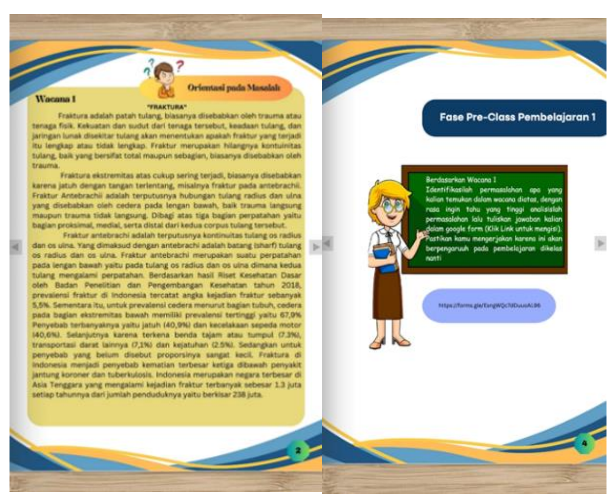
The e-module structural framework design is created in the form of a flowchart. The material prepared is movement system material which is divided into three learning activities, namely the skeletal and bone system, joints and muscles, and disorders of the movement system. Apart from that, learning tools were also created for this research, including a syllabus, learning implementation plan, and student worksheets. In implementing learning activities in the experimental class, the PBL model syntax with a flipped classroom approach was used, while in the control class, the conventional method usually applied by the teacher was used. The instruments prepared include assessment questionnaires by material experts, media experts, biology teachers, and students. Apart from that, problem-solving test instruments, learning independence questionnaires, and learning implementation evaluation sheets were also prepared. All of these devices were designed based on the results of the previous stage of analysis.

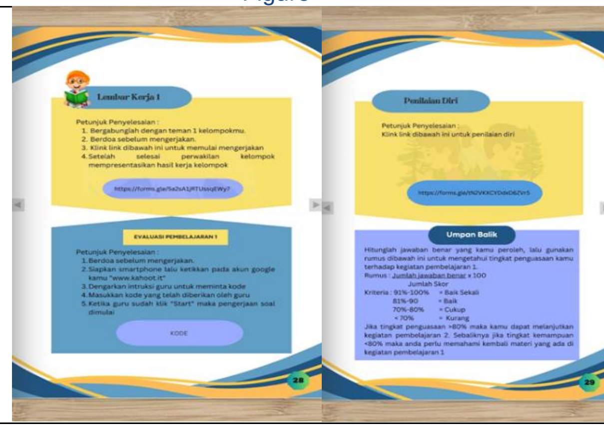
Development

At this stage, product development is carried out which produces teaching materials in the form of flipped classroom-based e-modules. This e-module is more interactive because it is equipped with a feature in the form of a button that makes it easier for students to go directly to the desired page. Apart from that, the e-module developed is designed using flipped classroom learning with the Problem-Based Learning (PBL) model so that at the beginning of each lesson there a activities designed for learning before class (Pre-class) and in class (In-class) by following PBL syntax, namely student orientation is carried out in the pre-class phase, organizing students, guiding investigations, developing and presenting results, as well as analyzing and Problem evaluation is carried out in the in-class phase. With flipped classroom learning, students will get their first exposure to learning via e-module and will certainly be better prepared to face learning in the classroom because they have previously carried out individual learning. The following outlines the design of the e-module which can be seen in Table 3.

Table 3. E-Module Design

No	E-module section	Figure
1	Cover	

No	E-module section	Figure
2	Button Features	
3	Material	
4	Examples of Problem Orientation Activities in Phases *Pre-Class*	

No	E-module section	Figure
5	Examples of After Learning Activities	

After product development is complete, it continues with instrument preparation and validation against experts. This is done to fulfill development research requirements. Validation was carried out by material experts (Munawaroh et al., 2023) media expert (Kundariati & Rohman, 2020) to find out the feasibility of the product being developed and validation for biology teachers (Bulkani et al., 2022) as well as students (Aprilia & Suryadarma, 2020) to find out the practicality of the product that has been developed. The results of product feasibility validation by material and media experts are presented in Table 4.

Table 4. Product validation results

No	Validator	Totality of Validation Scores	Maximum Score	Category
1	Media Expert	76	80	Very Good
2	Material Expert	75	80	Very Good

The results of the feasibility test by media experts and material in Table 4, it can be seen that the validation score by material experts reached 76 out of a maximum total score of 80. Meanwhile, the assessment by media experts showed a score of 75 out of a maximum score of 80. Both assessments are in the very good category which indicates that the e-module that has been developed is considered adequate to be tested in the context of biology learning. The next step involves a practical test by the biology teacher and students. The results of product practicality validation by biology teachers can be seen in Table 5.

Table 5. Practical Validation Results by Biology Teachers

No	Aspect	Totality of Validation Score	Maximum Score	Category
1	Material	26	28	Very Good
2	Language	15	16	Very Good
3	Media	39	40	Very Good
4	Learning	19	20	Very Good
Totality		99	104	Very Good

Meanwhile, the results of the feasibility test by biology teachers in Table 5 show that every aspect that has been assessed by the biology teacher refers to the very good category. So it can be concluded that the flipped class-based e-module product is practical for testing in biology learning about movement system material. After carrying out a practicality test on biology teachers, it was continued with a product readability test by students. This product readability test was carried out on students who had passed the movement system material. The results of the student readability test are presented in Table 6.

Table 6. Student Readability Test Results

No	Aspect	Average Score	Category
1	Material	24.4	Very Good
2	Ease of Operation	43.1	Very Good
3	Appearance	18.3	Very Good

Readability test results by students in Table 6 show that every aspect tested in terms of readability by students is in the very good category. The conclusion that can be drawn is that the flipped classroom-based e-module product is practical for testing in biology learning movement system material.

Implementation

The results of the implementation phase come from field trials. The field trial was carried out after going through a revision stage based on assessments and input from experts, as well as assessing the results of the readability test by students. The purpose of field trials is to evaluate the effectiveness of the product that has been developed.

The effectiveness of the flipped classroom-based e-module in developing problem-solving abilities in motion systems material is assessed through the use of problem-solving ability tests that have been validated by experts and tested empirically. In the next step, students are given pretest and posttest questions to evaluate initial and final abilities after studying movement system material using the e-module. The results of student scores can be seen in Table 7.

Table 7. Results of Descriptive Analysis of Problem-Solving Ability Data

Information	Experimental Class		Control Class	
	Pretest	Posttest	Pretest	Posttest
Sample	34	34	34	34
Standard Deviation Value	4.78	4.60	6.62	7.31
Minimum Score	40	75	40	60
Maximum Score	60	95	60	95
Average	52.95	88.09	50	81.32

The results as explained in Table 7, show that can be concluded that there was an increase in the posttest scores for students' problem-solving abilities, both in the experimental class and the control class. The average post-test score for the experimental class was higher than the control class. The next step is to carry out an N-Gain analysis, which aims to evaluate the extent of the increase in scores that occurred in the experimental class and control class in terms of problem-solving abilities. The results of the N-Gain analysis of problem-solving abilities in the experimental class were 0,75 in the high category and in the control class, namely 0,63, in the medium category. A clearer comparison of the N-gain scores can be seen in Figure 2.

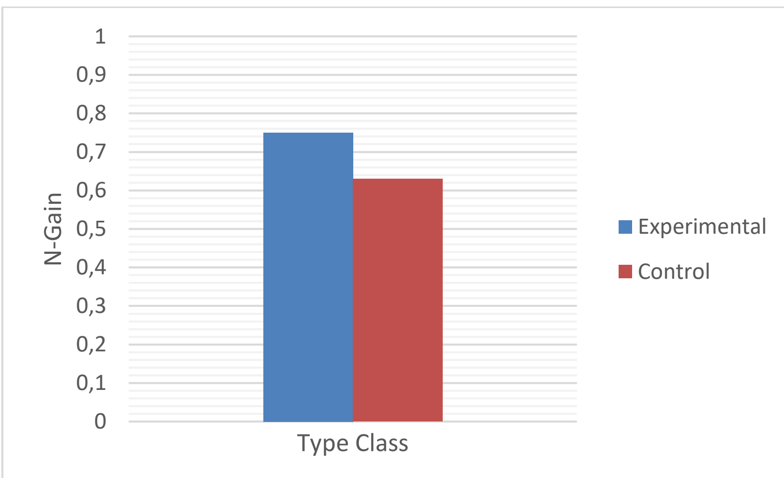


Figure 2. Comparison Chart of N-Gain Values for Problem-Solving Ability

This fact confirms that learning using flipped classroom-based e-modules is more effective in improving problem-solving abilities when compared to conventional approaches. The flipped classroom-based e-module that has been developed presents learning content that focuses on problems related to disorders in the human movement system. This allows students to relate the concepts they have learned to everyday life situations so that the learning process becomes more relevant to the context of their reality. The success of this learning helps students achieve the expected competencies more easily. Selecting the right learning resources has a positive impact on facilitating students' understanding of the material being taught (Fitriansyah, 2019).

The next step is to evaluate the effectiveness of the flipped classroom-based e-module on students' learning independence, which is measured through the use of a learning independence questionnaire that has been validated by experts. Students are asked to fill out a questionnaire before and after learning using the e-module. Differences in students' initial and final independence scores can be identified through the data in Table 8.

Table 8. Results of Descriptive Analysis of Learning Independence Data

Information	Experimental Class		Control Class	
	Pretest	Posttest	Pretest	Posttest
Sample	34	34	34	34
Standard Deviation Value	4.91	3.88	6.39	4.24
Minimum Score	50.00	80.00	41.25	71.25
Maximum Score	68.75	97.50	66.25	86.25
Average	58.46	89.12	51.51	79.71

Meanwhile, the results as explained in Table 9, show that can be concluded that there was an increase in the posttest scores for learning independence of students in the experimental class and control class. The average post-test score in the experimental class was higher than in the control class. The next step is to carry out an N-Gain analysis, which aims to evaluate the extent to which the increase in students' learning independence scores occurred in the experimental and control classes. The results of the N-Gain analysis of learning independence in the experimental class were 0,74 in the high category and in the control class, namely 0,58 in the medium category. A clearer comparison of the N-gain scores can be seen in Figure 3.

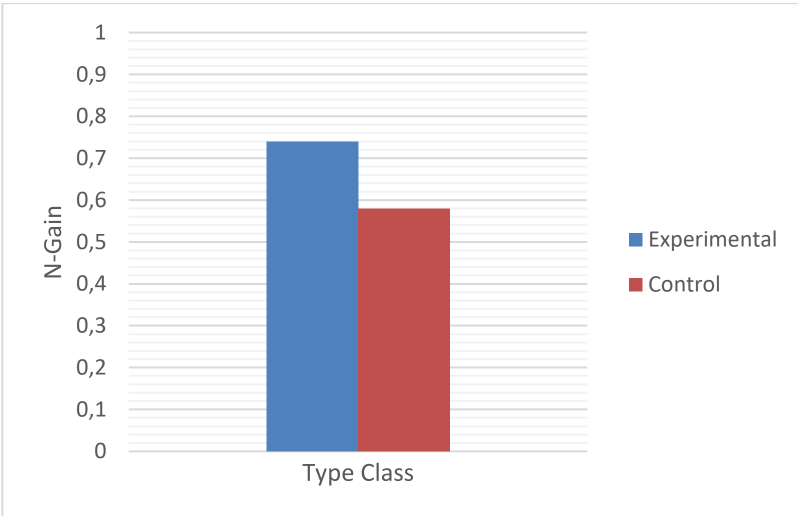


Figure 3. Comparison Chart of N-Gain Values for Learning Independence

This proves that learning carried out using flipped classroom-based e-modules is better at increasing learning independence compared to conventional learning. In independent learning, students are required to search for information, understand the content of the material, and solve problems on their own (Harfi et al., 2022). This finding is strengthened by the results of research conducted by Sulistiyono, (2022) which stated that the electronic module proved its effectiveness in increasing students' learning independence because the values of learning independence were assessed as high. Students with a high level of learning independence tend to be active in completing assignments given by the teacher according to their abilities to solve problems with a full sense of responsibility (Audhiha et al., 2022).

The effectiveness of the flipped classroom-based e-module product is then assessed through a statistical test approach. Before carrying out hypothesis testing, prerequisite tests are carried out, which include normality tests, homogeneity tests, variance-covariance matrix homogeneity tests, and multicollinearity tests. This prerequisite test aims to determine whether the data used meets the requirements for analysis using parametric or non-parametric statistical methods. The results of the normality test obtained a significance value for the problem-solving ability variable in the control and experimental classes was 0,184 and 0,063, while the significance value for the learning independence variable in the control and experimental classes was 0,106 and 0,187. If the sig value is > 0,05 then it can be concluded that the distribution data is normally distributed. The homogeneity test results obtained a sig value > 0,05 so it can be concluded that the data distribution comes from a homogeneous population. The results of the homogeneity test of the variance-covariance matrix obtained a Sig value of 0,560 > 0,05 so it can be concluded that the variance-covariance matrix is homogeneous concerning the independent variables.

The multicollinearity test aims to find out whether the two dependent variables have a very strong correlation (relationship) or not. The multicollinearity test was carried out using Pearson correlation. If the Pearson correlation value is <0,08 then multicollinearity does not occur, whereas if the Pearson correlation value is >0,08 then multicollinearity occurs. The results of the multicollinearity test can be seen in Table 9.

Table 9. Correlation Test Results

		Problem-Solving Ability	Learning Independence
Problem-Solving Ability	Pearson Correlation	1	0,272
	Sig	0	0,25
	N	68	68
Learning Independence	Pearson Correlation	0,272	1
	Sig	0,25	0
	N	68	68

Table 9, shows that the multicollinearity test shows a sig value <0,08 so it can be concluded that multicollinearity does not occur. The results of the four prerequisite tests above can conclude that parametric statistical analysis using multivariate tests can be carried out because all the prerequisite tests have been fulfilled with the results, namely that the data distribution is normally distributed, the data comes from a homogeneous population, the variance-covariance matrix is homogeneous for the independent variables, and multicollinearity does not occur. So, hypothesis testing can be carried out using multivariate tests. This hypothesis test aims to determine the differences in the use of flipped classroom-based e-modules on students' problem-solving abilities and learning independence. Multivariate test results can be seen in Table 10.

Table 10. MANOVA Test Results for Problem-Solving Ability and Learning Independence

Multivariate Tests				
Effect		Value	F	Sig
Class	Pillai's Trace	0.145	5.439^{b}	0.006
	Wilks' Lambda	0.855	5.439^{b}	0.006
	Hotelling's Trace	0.169	5.439^{b}	0.006
	Roy's Largest Root	0.169	5.439^{b}	0.006

The results as explained in Table 10, shows indicate that the significance level for Hotelling's Trace is 0,006 < 0,05. Therefore, it can be concluded that there is a significant difference in the use of flipped classroom-based e-modules on students' problem-solving abilities and learning independence. These findings show that the teaching materials that have been developed namely flipped classroom-based e-modules, are effectively used in learning activities.

The multivariate test was continued by looking at the test of the between-subject effect table to determine the differences in problem-solving ability and learning independence when using the flipped classroom-based e-module separately. The results of further multivariate tests can be seen in Table 11.

Table 11. Test Results of Test of between-subject effect

Test of Between-Subjects Effects				
Source	Dependent Variable	Mean Square	F	Sig
Class	Problem-Solving Ability	309.191	6.696	0.012
	Learning Independence	177.941	6.669	0.012

Result in Table 11, the test between the subject effect test on the problem-solving variable shows a sig value of 0,012 <0,05, which means there is a difference in problem-solving abilities in classes that use the flipped classroom-based e-module and those that do not. Likewise, the Test of between-subject effect test on the learning independence variable showed a sig value of 0,012<0,05, which means that there is a difference in learning independence in classes that use the flipped classroom-based e-module and those that do not.

Based on the results of the multivariate tests that have been carried out, this research has proven that the flipped classroom-based e-module teaching materials on movement systems are effectively used in biology learning to improve students' problem-solving abilities and learning independence. This is supported by research Sinmas et al., (2019) namely, the results of learning activities using e-module teaching materials with a flipped classroom learning setting increase because flipped classroom activities can make it easier for students to carry out problem-solving and information-seeking activities. This is also supported by the results of research conducted by Hidayati & Listyani, (2021) which shows that the e-module based on the flipped classroom approach meets the criteria of being valid, practical, and effective. The flipped classroom approach itself changes the way of learning by delivering content and activities outside of class, so that time in class can be used for active learning activities such as discussions, questions and answers, or other learning activities (Srinivasan et al., 2018; Pinontoan et al., 2021). Learning using the flipped classroom approach involves the use of materials such as videos, books, and sound recordings, which are then combined with collaborative activities in the classroom. Therefore, e-modules as digital learning resources are very suitable to be integrated with the flipped classroom approach (Hatanti et al., 2021).

The flipped classroom method is also suitable to be combined with the Problem-Based Learning model (Damayanti et al., 2020). This is reinforced by the results of research conducted by Cahyaningrum and Jaenudin, (2021) which shows that using e-module teaching materials based on a flipped classroom combined with a PBL learning model can create an innovative learning experience. With this approach, learning becomes more flexible, effective, and interesting, and students are more likely to participate actively because they are involved in problem analysis. This approach also has the potential to improve students' achievement, motivation, and problem-solving abilities, while encouraging their learning independence (Hidayatulloh et al., 2020; Lin, 2019; Khofifah et al., 2021).

Evaluation

Evaluation is applied in four stages, namely analysis, design, development, and implementation. The evaluation process is carried out at the end of each stage to assess the suitability of the specifications for the procedures carried out and the suitability of the results obtained as a reference and consideration for the next stage of the process. The evaluation was carried out to find out whether the flipped classroom-based e-module was suitable for use to improve students' problem-solving abilities and learning independence. So evaluation is also carried out after the flipped classroom-based e-module is implemented during classroom learning.

Conclusion

From the results of the research and development carried out, it can be concluded that the flipped classroom-based e-module developed is considered feasible based on assessments from material experts and media experts. Apart from that, this e-module is considered practical according to the assessments of teachers and students. Flipped classroom-based e-modules have also proven effective in improving students' problem-solving abilities and learning independence.

Acknowledgment

The author would like to thank the Department of Masters in Biology Education, FMIPA UNY for the funding assistance provided for master's research and SMA N 1 Seyegan for permission and support in conducting research.

Conflicts of Interest

The author declares that there is no conflict of interest regarding publication in this journal.

Author Contributions

A. D. Ayunda: Designing research, conducting research, data analysis, completion, draft preparation, writing manuscript, and revision. **H. Hasanah:** Data analysis, review and revision. **N. A. Ariyanti:** Data analysis, review and revision.

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