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Developing a Biology E-Module Based on Pjbl-Steam Model to Improve Students' Collaboration Skills

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ABSTRACT
Digital inequality and the pandemic have exacerbated the learning crisis, caused some learning loss, also fostered students' individualistic attitude, which resulted in poor collaboration skills. Furthermore, the models and approaches in the teaching material activities have not reflected the stages that encouraged the practice to enhance collaboration skills. Meanwhile, collaboration skills can be trained and developed by selecting the right teaching materials that are integrated with appropriate learning models. The development of PjBL-STEAM-based E-Module is believed to be able to improve students' collaboration skills. This study used a quasi-experimental design with basic random sampling. There were two study groups: the experimental and the control groups. The instruments used in this study were a self-assessment questionnaire measuring students' collaboration skills and teachers' observation sheets that aligned with the collaboration skill indicators. ANCOVA test was used to analyze the data. The findings showed that the E-Module has no significant effect on students' collaboration skills (α=0,213), while the covariates indicated some factors that significantly affect the improvement of students' collaboration skills (α=0,004). The validation results of the PjBL-STEAM-based E-Module suggested that it is highly valuable to implement in the teaching and learning process.

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1. INTRODUCTION

The challenges of the 21st century require students to have the necessary skills, including collaboration and problem-solving skills. Collaborative skills in learning function as a link between interactivity and learning achievement because active collaborative learning is a medium that connects the two (Chan, 2019). Collaboration skills should be facilitated, and students should be prepared to develop the skills needed to interact effectively in groups (Weiss et al., 2017). Tama (2018) states that collaboration skills are important for enabling humans to socialize, be sensitive to their surroundings, and manage their egos and emotions well. However, digital inequality and the Covid19 pandemic have added to the learning crisis, causing some learning loss and fostering individualistic attitudes in students, leading to poor collaboration skills. Previous studies have shown that increased participation in inappropriate internet-related activities among learners is associated with greater psychological distress due to the pandemic. It is argued that online activities can prevent a person from engaging in normal social behavior and cause psychological distress (Xu, 2021). Julita's (2016) study suggests that students' cooperation level and social interaction are still low; thus, they need to practice and develop cooperative skills. Collaborative skills have been drilled through group discussion and presentation activities, but some students rely on other students who are more active (Fitriani et al., 2019). Active students hereby dominate learning. Kusuma et al., (2019) state that students' collaboration skills and higher-order thinking skills are still poor because the learning process is still centered on the teachers.

The results of a needs-analysis interview with the Al Muslim High School Biology teacher in East Java in July 2022 showed that the currently implemented Biology lessons still faced some problems in improving students' collaboration and problem-solving skills. This was caused by several factors, such as the educators' difficulties in developing teaching materials needed by students to gain meaningful experiences and search for information through fact discoveries and fun activities. The approaches and activities in the teaching materials still did not reflect the stages that enhanced these skills. Students were asked to form small groups, but the activities were just working together without emphasizing the essence of collaboration, making learning less meaningful. The needs analysis on students in class XI (second year/11th graders) of Senior High School (SMA) Al Muslim using the student collaboration skills questionnaires showed that 38.15% of students still could not fully exhibit collaboration skills. This was shown in the indicator results: working productively (22.80%), showing respect for opinions (55.26%), showing flexibility and compromise (21.05%), and showing responsibility and contributing actively (42.10%).

Accordingly, a solution was needed to improve students' collaboration skills. Collaboration skills can be trained and developed by selecting the right teaching materials that are integrated with appropriate learning models. Teaching materials can help teachers to design learning and aid students in acquiring learning competencies (Kimianti & Prasetyo, 2019). Modules have become relevant teaching materials in this digitalization era. The key role of the module is to assist teachers in designing learning in their classes (Pepin et al., 2017). The design of learning activities in modules that focus on developing the 21st-century skills has the potential to be implemented effectively in learning. Electronic modules are an option that can increase students' enthusiasm and interest in learning because printed modules were not really interesting, had limited interactivity, and could not really convey historical messages through pictures and videos (Satriawati, 2015). On the other hand, E-Module can describe the design of learning activities according to the learning model and also facilitate the implementation of the required assessment.

Degeng (2013) argues that the success of achieving learning objectives depends on the teacher's thoroughness in choosing the appropriate learning model. One of the learning models that can improve collaboration and problem-solving skills and can be integrated into E-Modules is Project Based Learning (PjBL). Whatley, (2012) states that PjBL is a constructivist and collaborative learning that facilitates students to work together to solve problems with the knowledge they have. The implementation of PjBL that is connected to e-learning and blended learning can improve students' life skills in learning biology through project activities that are based on everyday life. Nevertheless, learning biology with PjBL during the pandemic still has its drawbacks such as a lack of understanding of concepts and difficulties in finding the materials needed. To overcome this challenge, the use of information and communication technology and the implementation of practical concepts in real-life scenarios can be emphasized and offered as a solution. In addition, e-learning and blended learning can directly facilitate PjBL and encourage creativity and collaboration among students, eventually generating more active learners (Hizqiyah et al., 2023). The study proved that the PjBL model alone was still not enough to improve students' collaboration skills so the right learning approach and the use of appropriate technology are needed. Therefore, PjBL with the STEAM approach will be more effective.

Lukitawanti et al., (2020) found that the use of the PjBL-STEM (Science, Technology, Engineering, and Mathematics) model in learning, supported by formative assessments, can produce higher problem-solving skills than learning only with the PjBL model. Projects in PjBL-STEM often involve complex problem-solving that requires diverse perspectives and knowledge. In this context, students need to collaborate to gather information, analyze problems, and develop solutions. Collaboration enables students to share ideas, integrate different knowledge and skills, and identify the best strategies to tackle complex challenges. By incorporating the elements of PjBL-STEM into learning, students are provided with opportunities to actively engage in collaborative situations that build their social, interpersonal, and collaborative skills. This helps them become effective team members, gain a better understanding of cooperation, and be ready to work in real-world environments that require collaboration, including in the field of STEM.

Meanwhile, Spikol et al., (2017), asserted that Science, Technology, Engineering, Art, and Mathematics (STEAM) approach engages students in design and engineering tasks, which encourage students to exploring their science and math skills through creativity, expression, and visual aspects. This approach also supports logical and material thinking. Through design and engineering tasks, students are given the opportunity to apply concepts of science and mathematics in real and practical contexts. They can utilize technology and engineering skills to design, construct, and test solutions or products. This approach encourages critical thinking, collaboration, and creative problem-solving. While project-based learning can focus on one or more specific contents, STEAM offers great opportunities to create projects that integrate elements of science, mathematics, technology, and even art (Miller, 2017). Therefore, integrating the PjBL learning model with STEAM approach will be more effective. The STEAM approach provides active experiences to students and encourages them to find solutions for any problems that arise, thus increasing students engagement in learning. The STEAM approach encourages creative problem-solving and innovative thinking. By facing challenges in projects, students are encouraged to think critically,

discover solutions, and collaborate with team members or peers. This enhances student engagement in the learning process as they feel actively involved and responsible for overcoming the problems.

The STEAM approach also encourages students to develop problem-solving skills, critical thinking skills, and collaborative skills (Messier, 2015). The STEAM approach provides a framework that integrates problem-solving skills, critical thinking skills, and collaborative skills within a meaningful learning context. This helps students develop abilities that are relevant to the real world and prepares them for future challenges. The PjBL-STEAM model encourages students to gain a deeper understanding through active exploration by engaging in real-world challenges and problems with all of their integrated components (Annisa et al., 2018). The PjBL-STEAM model provides a holistic and integrated approach to learning. By engaging students in active exploration and real-world challenges, this model helps students gain a deep understanding, develop problem-solving skills, and see the interconnections between STEM disciplines in meaningful contexts. Fatimah (2017) demonstrated that the implementation of the PjBL-STEAM model could improve 21st century skills such as critical thinking and problem-solving skills, creativity and innovation, communication and collaboration, information literacy, media literacy, technology literacy, flexibility, and adaptability. The implementation of the PjBL-STEAM model can have positive effects on a wide range of 21st century skills, equipping students with the abilities necessary to thrive in a rapidly evolving world.

2. RESEARCH METHOD

This development research aimed to create a Biology E-Module based on the PjBL-STEAM model to improve students' collaboration skills. The research and development model used in this study was developed by Lee & Owens (2004) using quasi-experimental methods and simple random sampling techniques. This model was chosen because it has a well-organized, flexible, and clear structure at each stage and is excellent in developing multimedia products (Lee & Owens, 2004). The stages in this development model were: a) assessment/analysis comprising a needs assessment or front-end analysis; b) design; c) development; d) implementation; and e) evaluation. Pre-test-Post-test Control Group Design adopted is shown in Table 1. However, only the experimental group was treated.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experiment Group (X Ar Rahman)	O_1	X	O_2
Control Group (X Al Hakam)	O_1	-	O_1

Description:
O1 : Pretest (before learning)
X1 : Lesson using E-Module PjBL-STEAM
O2 : Posttest (after learning)

The participants in this study were the tenth graders (freshmen) of SMA Al Muslim (Ar Rahman and Al Hakam classes) of the 2022/2023 academic year. This study was conducted in two sample classes, the first was the experimental class and the second was the control class. The classes were decided by equivalence testing using the IBM SPSS 21 program vis-à-vis the Al Muslim High School entrance test scores. The experimental class and control class were determined using simple random sampling technique. The researcher then developed the E-module and acted as the model teacher implementing it in the experimental class.

The data was collected using questionnaires distributed to students to self-assess their collaboration skills and observation sheets used by teachers to assess students' collaboration skills. The collaboration skills instrument is based on the formulation by Greenstein (2012). Rubric for assessing collaboration skills is shown Table 2.

Table 2. Rubric for assessing collaboration skills

Skill	Exemplary (4)	Proficient (3)	Basic (2)	Novice (1)
consist of working productively	We used all our ime efficiently to stay focused on the task and produce the required work. Everyone did his or her assigned duties and sometimes more	We worked together well and for the most part stayed on task until we completed our work. Each person performed nearly all assigned duties	We worked together sometimes, but not everyone contributed or did his or her job, making it hard finish our work	We really didn`t work together very well . Everyone wanted to do his or her own thing and tell others what to do rather than focus on the task

Skill	Exemplary (4)	Proficient (3)	Basic (2)	Novice (1)
showing respect for opinions	Everyone respectfully listened and discussed ideas that were shared	Members listened and interacted respectfully most of the time	Some people had difficulty being respectful of others~ ideas	Members were unwilling to listen to others and were argumentative with teammates
showing flexibility and compromise	Everyone was flexible in working together to achieve a common goal	We usually were able to compromise to move or work forward	If more people compromised, we would have moved forward faster.	There was a lot of disagreeing, and some individuals wanted it only their way
showing an attitude of responsibility, and contributing actively	Everyone did their best work and followed through on assigned tasks	Most people followed through on their parts	It was hard to get everyone to do his or her part	We really couldn`t depend on everyone to do his or her part

Data were analyzed using ANCOVA, including the questionnaires for the experts in learning environmental change materials, experts in biology learning media, and the practicality questionnaires by field practitioners. The results of the analysis were used as a feasibility testing for the modules that have been developed. If the results of the analysis show validity, then the e-module can be implemented. However, if the results of the analysis are not valid, further revisions are required. The equation used in the data analysis of this

$$V = \frac{JS}{JM} \, x \, 100\%$$

study is as follows:
Note:
V = Validity level
JS = Total scores obtained
JM = Total maximum scores
100% = Constant

The assessment questionnaire data from the validator was evaluated based on the validity criteria which was then analyzed using the assessment criteria listed in the following table 3:

Table 3. Criteria for the Validity of Validation Results

Percentage	Conclusion
81%- 100%	Highly valid, can be used without revision
61%- 80%	Valid, can be used with minor revision
41%- 60%	Not so valid, not suggested for use, major revision isrequired
21%- 40%	Invalid, should not be used, major revision is required
1%- 20%	Highly invalid, must not be used

(Akbar, 2013)

3. RESULT AND DISCUSSION

First Stage: Analysis/Assessment

The analysis/assessment stage is the stage of describing the problem in the learning process at the site in this study. The analysis phase consists of needs assessment/analysis and front-end analysis. The results of the two stages are described as follows.

Results of Need Assessment

The Needs analysis data were obtained from interviews with the biology teachers at SMA Al Muslim East Java. The results of the interviews revealed that the biology learning that had been implemented still faced some problems in improving students' collaboration skills. This was due to several factors. While teachers already had the teaching materials for learning, innovation was still needed considering the current conditions. It was because teaching materials owned by the teachers could not facilitate students to gain meaningful experiences and search for information through fact discoveries and fun activities. The approaches and activities of the teaching materials still did not reflect the stages of developing students' collaboration skills. On the topic of environmental change,

for instance, students were asked to form small groups to do some projects. However, the activities were just working together without emphasizing the essence of collaboration, such as working productively, showing mutual respect, showing flexibility and compromise, showing responsibility and contributing actively. In addition, the teachers still had difficulties guiding students to find innovations in their projects because they had not integrated the learning models with the learning approaches that can facilitate the mastery of 21st-century skills. Thus, it was significant to develop PjBL-STEAM-based teaching materials that provide activities that can enhance students' collaboration and innovation skills.

The needs analysis results of participants in this study were procured by distributing collaboration skills questionnaires to the students. The results showed that 38.15% of students still could not fully exhibit collaboration skills. This was shown in the indicator results: working productively (22.80%), showing respect for opinions (55.26%), showing flexibility and compromise (21.05%), and showing responsibility and contributing actively (42.10%). The needs analysis of both teachers and students also resulted in the designs for the development of teaching materials in the form of E-Modules that were representative and in accordance with students' needs. The development of this E-Module was supported by the facilities and infrastructures owned by students and provided at school. Students already had their own cellphones and/or laptops as a tool to use the E-Module. Furthermore, SMA Al Muslim school supports students' learning process with a reliable Wi-Fi network and Learning Management System (LMS), namely My Al Muslim, and encourages students to explore the environment as a learning resource.

Results of Front-End Analysis

This stage aimed to collect accurate data on the existing problems in the field, which were later used as a basis to determine the solutions to be developed. The data was obtained through several stages of analysis: audience analysis, technology analysis, task analysis, situational analysis, objective analysis, media analysis, extant data analysis, and cost analysis. The audience analysis aimed to determine students' backgrounds, learning characteristics, and prerequisite skills. The observation results showed that students came from a diverse demographic environment and thus had different initial abilities and learning characteristics. The technology analysis aimed to identify the types of technology available in the field. The observation results showed that all students had already had their personal smartphones and/or laptops with a good internet connection to support learning. The task analysis aimed to determine tasks that support better learning. The observation results showed that the tasks were given in the form of projects and small groups, but project innovation and the essence of collaboration were not fully optimized. The critical incident analysis aimed to determine the boundaries of task development in e-modules that are important for improving integrated skills. The situation analysis aimed to determine the flow of preparing the solutions based on other analyses in the previous stages so that the delivery of solutions aligned with the needs in the field. The objective analysis aimed to analyze the research and development objectives. The media analysis aimed to determine the appropriate media for implementing solutions. This study developed media in the form of a website-based electronic module (e-module). The website was chosen as the e-module development platform because it can be accessed easily anywhere and anytime via a smartphone, laptop, and other devices. Additionally, the data used in the analysis were also included in the analysis of existing data (extant data analysis), which aimed to identify data already available in the field in relation to the solutions being developed. This means that the needs analyses on the field need to be developed to serve as the basis for developing the E-Module. Indeed, extant data analysis was conducted by reviewing the learning outcomes and the learning objectives and conducting class observations on the tenth graders in SMA Al Muslim. Meanwhile, the cost analysis aimed to identify aspects of expenditure needed in conducting research.

Second Stage: Design

The designing phase was conducted in September 2022. At this stage, the learning devices were designed using a predetermined model to support the learning process at SMA Al Muslim East Java. The initial E-module design was also developed in this stage to improve students' collaboration skills with specifications that had been adjusted based on the needs analysis results

Third Stage: Development and Implementation

This stage was executed by creating storyboards, packaging interface designs, developing content presentations, making revisions or improvements, and product packaging. The E-Module was developed based on a storyboard created in accordance with the learning outcomes in Phase E of Class X regarding environmental change. The interface design development resulted in the form of a home, introduction, and instructions for using the E-Module. The e-module was developed starting from instructions for use, concept maps, teaching module summaries, handouts, Bio Activity I, II, and III, Bio Summary, Bio Glossary, Evaluation, and the author's biography. The features developed in the E-Module were Bio Smart, Bio Quotes, Bio Fun Facts, Mindmap, Bio Iman and Taqwa (Bio IMTAK), Bio Challenge, Bio Check, Bio Web, Bio Activity, Bio Summary, Bio Glossary, Bio Feedback, and Bio Nextstep. E-Modules are packaged google site web-based because they are more practical

to use and can combine images, text and videos into one so that it attracts students' interest in reading and learning it. In accordance with the results of the study Abadiyah et al., (2018) that The flipbook is commonly employed in the educational process due to its ability to combine text, animation, video, and sound, which captivates the readers' attention. As a result, the flipbook possesses an advantage over other instructional materials in terms of its format. Flipbook is also a website-based teaching material similar to the Google site. The results generated in this stage were teaching materials that were both valid and ready to be implemented to improve students' collaboration skills and product validation results.

Table 4. Results of Validation by the Content Experts

No	Aspects	Score	Percentage (%)	Criteria
1.	Content coverage	3.75	93.75	Highly Valid
2.	Content accuracy	4	100	Highly Valid
3.	The depth of the content	4	100	Highly Valid
4.	Content contextuality	3.5	87.5	Highly Valid
5.	Legal compliance	4	100	Highly Valid
6.	Content delivery	3.5	87.5	Highly Valid
Average of All Aspects		**3.79**	**94.79**	**Highly Valid**

Table 4 showed that the content in the Biology E-module based on the PjBL-STEAM model was appropriate for use in the learning process on the topic of environmental change for Class X or the tenth graders.

Table 5. Results of Validation by the Module Experts

No	Aspects	Score	Percentage (%)	Criteria
1.	Component of Delivery	5	100	Highly Valid
2.	Content Eligibility	5	100	Highly Valid
3.	Language Eligibility	4.6	92	Highly Valid
4.	PjBL-STEAM Learning Syntax	4.8	96	Highly Valid
5.	Evaluation	5	100	Highly Valid
Average of All Aspects		**4.85**	**96.83**	**Highly Valid**

The results of validation by the module expert showed that the Biology E-module based on the PjBL-STEAM model was feasible to use in the learning process on the topic of environmental change for Class X or the tenth graders.

Table 6. Results of Validation by the Field Practitioners

No	Aspects	Score	Percentage (%)	Criteria
1.	Component of Delivery	5	100	Highly Valid
2.	Content Eligibility	5	100	Highly Valid
3.	Language Eligibility	4.6	92	Highly Valid
4.	PjBL-STEAM	4.8	96	Highly Valid
5.	Learning Syntax	5	100	Highly Valid
6.	Evaluation	4.67	93	Highly Valid
Average of All Aspects		**4.85**	**96.83**	**Highly Valid**

The results of validation by the field practitioners showed that the Biology E-module developed based on the PjBL-STEAM model obtained a percentage of 96.83%, which was in the Highly Valid category. Therefore, it can be concluded that the Environmental Change E-module can be implemented in students' learning.

Implementation

At this stage, activities for the teacher and students were prepared. The researcher acted as the model teacher and prepared the learning devices, especially the E-Module that has been developed. The participants in this study were 25 students of Class X Ar Rahman, who were learning the environmental change materials. Students were prepared by directing them to follow the instructions for using the Environmental Change E-Module during the learning process. During the learning process, the observers, i.e. a colleague and the teacher, were prepared. Preparations also included the arrangement of the implementation schedules, the distribution of E-Module teaching media and technical preparations needed by students. This research was conducted in January-March, the even semester or the second half of Academic Year 2022/2023 at SMA Al Muslim.

The evaluation was done after the implementation. At this stage, the developed E-module was improved and revised while analyzing students' collaboration skills. The collaboration skills were assessed through students' self-assessments and the teachers' observations. Figure 1 shows the level of collaboration skills of students.

Fourth Stage: Evaluation

The evaluation was done after the implementation. At this stage, the developed E-module was improved and revised while analyzing students' collaboration skills. The collaboration skills were assessed through students' self-assessments and the teachers' observations. Figure 1 shows the level of collaboration skills of students.

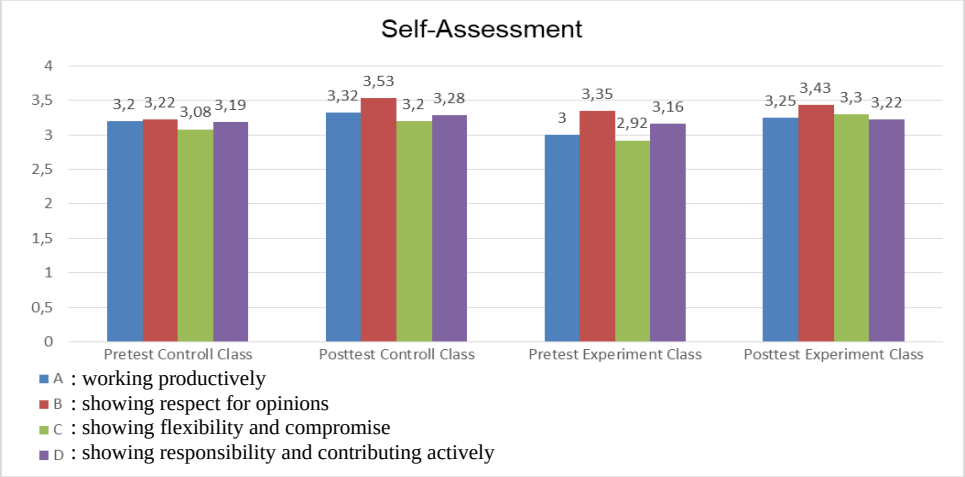

Figure 1. Self-Assessment

Based on figure 1 both the control class and the experimental class had an increase in each indicator of collaboration skills through student self-assessment, even though the control class was not given treatment/not given an e-module based on the PjBL-STEAM model. Learning in the control class uses the PjBL model only. The indicator shows flexibility and compromise in the control class with an average score of 3.53, while in the experiment it reaches a score of 3.43. This shows that the two classes have almost reached the exemplary level. Overall, both the control and experimental classes showed the achievement of collaboration skills at the proficient level.

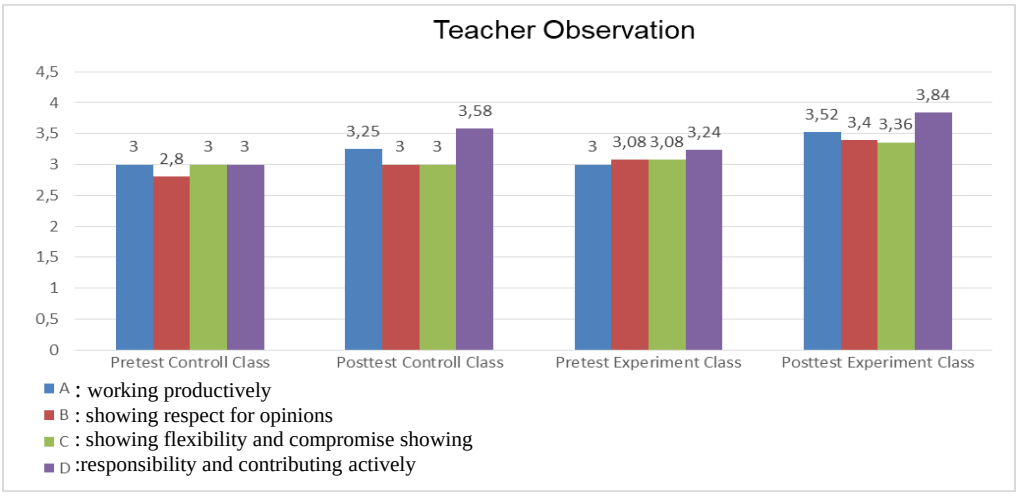

Figure 2. Teacher Observation

Based on figure 2 the indicators of collaboration skills that did not increase in the control class were showing flexibility and compromise, the pretest and posttest scores remained 3, while the other indicators increased but were still at the proficient level. The indicators showing responsibility and actively contributing have almost reached the exemplary level. In the experimental class all indicators of collaboration skills have increased. The working productively indicator has increased from a score of 3 at the pretest to 3.5 after the posttest. Likewise with the indicator showing responsibility and contributing actively from a score of 3.24 at the pretest to

3.84 after the posttest. The indicators of working productively and showing responsibility and contributing actively have almost reached the exemplary level. All indicators of collaboration skills show a proficient level.

The results were then analyzed using the ANCOVA test, which had previously been subjected to a prerequisite test consisting of a normality test and a homogeneity test. The normality test results on students' self-assessment in Table 7 showed significant values in the control and experimental groups, respectively α=0.087 and α=0.145, with α≥0.05 indicating that the data was normally distributed. The homogeneity test results in Table 5 showed that the data was homogeneous. Furthermore, the results of the ANCOVA test in Table 8 showed a significance value of α=0.213, with α≥0.05 implying that the E-Module has no significant effect on improving students' collaboration skills. However, the covariates showed a value of α=0.004, with α≤0.05 indicating some factors that significantly affect the improvement of students' collaboration skills. These factors can be internal and external, i.e., students' own motivation and the motivation given by the model teacher.

Table 7. Normality Test on Students' Self-Assessment Collaboration Skills

No.	Groups	Normality (Kolmogorov Smirnov)	Homogenity (Levene Test)
1	Control (Non-*E-Module*)	0.087	0.074
2	Experimental (*E-Module*)	0.145	0.074

Table 8. Results of ANCOVA Test on Students' Self-Assessment Collaboration Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	306.053[a]	3	102.018	3.699	**.018**
Intercept	470.271	1	470.271	17.050	**.000**
Class	43.971	1	43.971	1.594	**.213**
Covariates	255.577	1	255.577	9.266	**.004**
Class * Covariates	49.680	1	49.680	1.801	**.186**
Error	1241.213	45	27.583		
Total	79468.000	49			
Corrected Total	**1547.265**	**48**			

The results of the normality test on students' observation skills from the teacher's observations in the control and experimental groups each showed a value of α=0.074 and α=0.091, with α≥0.05 indicating that the data was normally distributed. The homogeneity test results on students' collaboration skills from the teacher's observations in Table 9 showed a value of α=0.458, with α≥0.05 indicating that the data was homogeneous. Furthermore, the results of the ANCOVA test showed that the E-Module had no significant effect on improving students' collaboration skills, indicated by the value of α=0.378, which was larger than 0.05, as shown in Table 10. Nonetheless, the covariates showed a value of α=0.000, with α≤0.05 indicating the existence of some factors that significantly affect the improvement of students' collaboration skills. These factors can be internal and external, i.e., students' own motivation and the motivation given by the model teacher.

Table 9. Normality Test on Students' Collaboration Skills from the Teacher's Observations

No.	Groups	Normality (Kolmogorov Smirnov)	Homogenity (Levene Test)
1	Control (Non-*E-Module*)	0.074	0.458
2	Experimental (*E-Module*)	0.091	0.458

Table 10. Results of ANCOVA Test on Students' Collaboration Skills from the Teacher's Observations

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	63.345[a]	3	21.115	16.967	.000
Intercept	71.225	1	71.225	57.233	.000
Class	.986	1	.986	.792	.378

Covariates	59.636	1	59.636	47.921	.000
Class * Covariates	1.384	1	1.384	1.112	.297
Error	56.001	45	1.244		
Total	9473.000	49			
Corrected Total	**119.347**	**48**			

The results of ANCOVA test on students' collaboration skills after using the E-Module were not very significant. This was because the control class used the Project Based Learning (PjBL) model, while the experimental class used the PJBL model that was integrated with the STEAM approach. Both of these models supported learning with collaborative activities even though the control class was not given an E-Module. The E-Module could provide an accessible and flexible collaborative platform, but using technology alone was insufficient to improve students' collaboration skills. Collaboration skills concern deeper aspects of interpersonal and communication than simply using technological tools. Social and emotional skills, such as communication ability, cooperation, conflict management, and empathy, are crucial foundations for effective collaboration. It is important to explicitly develop students' social and emotional skills through relevant approaches within the context of PBL. Collaboration skills, such as effective communication and teamwork, can be challenging for students. Lack of understanding of how to communicate and collaborate effectively in the context of learning can impact their progress in collaboration skills.

This is also caused by the ineffective interaction among elements in the learning process. This interaction can include the lack of support from peers, the lack of motivation, self-confidence, high curiosity, physiological conditions (health), and the ability to interact/communicate with peers and teachers. The lack of peer group support and environment support can influence students' trust because peers are crucial in fostering students' trust (Choi et al., 2018)). Based on these factors, the indicators of collaboration, such as working productively, showing respect for opinions, demonstrating flexibility and compromise, showing responsibility and active contribution, have not been optimally demonstrated due to the interaction/communication factor among group members and the lack of peer group support. Additionally, internal factors within students can also affect collaboration skills, namely self-regulated learning. Self-regulated learning refers to students' ability to self-manage their learning to achieve success or learning goals. Students with high self-regulated learning actively engage in completing their group tasks (Hamida, 2022). In this study, it is possible that students' self-regulated learning is still low, resulting in less active involvement in completing their group tasks.

Factors outside the E-Module, such as the same teaching methods, similar class structures, or the teacher's approach to collaboration, can affect students' collaboration skills in ways that are independent of the existence or use of the E-Module. Moreover, the variability in students' initial collaboration skills at the time of the pre-test indicated that students in the control and experimental classes had similar levels of collaboration skills before the E-Module intervention was implemented. In this case, the differences in collaboration skills between the control and experimental classes were not very significant, regardless of the presence or use of the E-Module (Tabachnick et.al., 2013). The developed E-Module was not like conventional modules. The developed e-module was integrated with the STEAM-approach PjBL learning model syntax. Indeed, the E-Module has already provided a performance assessment as a formative assessment to help teachers in assessing students' performance from the project planning stage to the project evaluation stage.

4. CONCLUSION

This study concluded that the PjBL-STEAM-based Biology E-Module on the topic of environmental change has no significant effect on improving the collaboration skills of the tenth graders of SMA Al Muslim, East Java. This could have resulted from the challenging factors in improving collaboration skills, such as differences in abilities, lack of social skills, and differences in preferences in working collaboratively, which could hinder the achievement of improved collaboration skills. It could also be caused by the variability in students' initial collaboration skills at the time of the pre-test, indicating that students in the control and experimental classes had similar levels of collaboration skills before the E-Module intervention was implemented. The E-Module developed by the researcher has been validated by the validator and produced effective results, and thus can be implemented in learning biology on the topic of environmental change for the tenth graders in senior high schools. Further research is needed and can be done by comparing the development of E-module using different learning models and approaches.

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