# Developing a project-based learning-based e-module to enhance critical thinking skills on vocational students

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Received March 28th 2024; Revised August 18th 2024; Accepted August 28th 2024

**Cite this** https://doi.org/10.24036/jptk.v7i3.37923



**Abstract:** This study aims to develop a digital simulation and communication e-module based on Project Based Learning by using Moodle application to improve critical thinking skills in the field of computer and network engineering. The main focus of this study is to assess the validity, practicality, and student responses to the developed e-module design. The study employed a Research and Development (R&D) with the 4D model, including Define, Design, Develop, and Disseminate. The instrument used was a set of questionnaires on validation, user practicability, and student responses to the e-module, distributed to 25 students. The e-module was rated as valid by media experts (82%) and material experts (84%) and very practical according to teacher assessment (89.09%) and practical according to student assessment (84.07%). The results showed that students' scores after using the e-module were higher than the scores before using the e-module, indicating the effectiveness of the e-module in improving students' critical thinking skills and understanding of the learning. The findings emphasize the importance of technology integration in vocational high schools to prepare students for future jobs and encourage innovation in 21st century learning methodologies.

**Keywords:** e-module; Simulation and digital communications; Vocational schools; Quality education

## 1. Introduction

Vocational High Schools (SMK) should be able to prepare skilled graduates to face the challenges of the 21st century. SMK seeks to develop a workforce capability to adapt in the business area and transition to the industrial sector as well as to equip graduates with relevant skills and knowledge (Auvinen et al., 2020; Darmawan et al., 2020; Hamid et al., 2020; Sudira, 2019). Apart from hard skills, vocational education graduates must also have soft skills to be able to compete in the working environment (De Vos et al., 2021; Dzulkurnain et al., 2024; Fitra et al., 2024; Nasution et al., 2024; Pinna & Pitzalis, 2024; Putra et al., 2024). Data from the Programme of International Student Assessment (PISA) in 2018 showed that Indonesian students have average learning outcomes with a score of 396. This score is lower than Thailand with a score of 426. This means that the education level of students in Indonesia still doesn't meet the average score compared to other country members of the Organization for Economic Co-operation and Development (OECD). The main cause of the ranking obtained is low soft skills and expertise the students have.

Soft skills are the ability to behave adaptively and constructively, which enable individuals to be professional in facing the challenges of life (Sari et al., 2024; Syahril et al., 2022). The individuals who do not acquire soft skills will not be able to compete in the working environment because soft

skills predict success in life (Chan & Luk, 2022; Supandee & Yachulawetkunakorn, 2023). Based on studies about the competencies needed in the 21st century, soft skills and hard skills are equally important in the engineering field (de Água et al., 2020). Critical thinking skills are high-level thinking skills that include creative and cognitive thinking as well as the ability to combine and assess collected information (Marin & Suparno, 2024; Sulistyanto et al., 2024). This ability can increase awareness and intelligence as well as comparing and solving problems (Budiarto et al., 2024). If everyone had the ability to think critically, then problems would become easier and simpler to solve. Critical thinking in solving problems is one of the 21st century skills that students must acquire (Pamungkas et al., 2020). This is because the working environment and industry in the 21st century requires workers who have critical thinking skills and are able to solve problems.

To develop soft skills, learning in vocational education begins with a predetermined curriculum and includes soft skill development content (Beltrán et al., 2023). It will be easier for teachers to design learning activities that are relevant to the competencies needed by the business and industrial world. One of the most important subjects in the computer and network engineering department for forming soft skills is simulation and digital communication subjects (Klave & Cane, 2024). Simulation and digital communication subjects in computer and network engineering curriculum require a learning model that produces practical experience, reflection, and active knowledge construction (Pan & Isnaeni, 2024; Sindi et al., 2024). Project-based Learning is a learning model that can help students improve their critical thinking skills (Jalinus et al., 2019, 2020; Syahril et al., 2022). Integrating Project-based Learning in the learning process has the potential to improve students' critical thinking skills (Jalinus et al., 2023; Jalinus & Nabawi, 2018; Le et al., 2022).

The learning process will be effective if it is supported by dynamic learning media and methodologies that allow students' potential to develop optimally (Al-Awidi & Al-Furaih, 2023). Teaching materials, such as innovative ebooks with video, animation, and audio, make learning more effective, efficient and relevant (Kudryavtseva et al., 2023; Rokhim et al., 2023). It is especially supported by Moodle. The Moodle application supports interactive learning media because it does not only focus on writing but also includes motion animation, video, and audio, so that learning becomes more fun (Plyer et al., 2024; Yang, 2024). This combination helps students visualize abstract simulation and digital communication lesson material into concrete visualization. Therefore, innovation is needed in developing e-modul in simulation and digital communication courses to satisfy the students and make them understand the material well and develop students' soft skills. Thus, this study aims to develop a digital communication and simulation learning e-module based on Project-based Learning using the Moodle application to improve the critical thinking skills of computer and network engineering students of vocational high school.

## 2. Methods

### Type of study

This study belongs to research and development (R&D) which aims to produce and test the effectiveness of certain products (Branch, 2009). The development model used for this research design was 4-D, which includes the Define, Design, Develop, and Disseminate stages as shown in Figure 1.

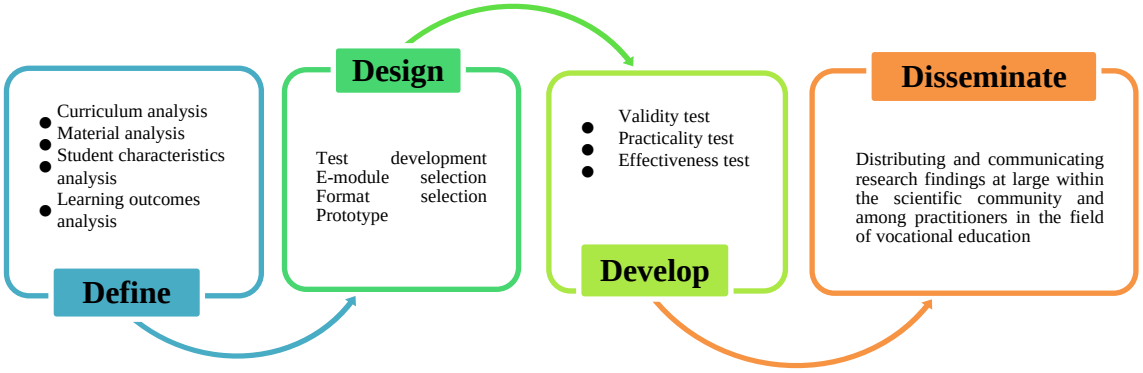


Figure 1. 4-D model development procedure

***Define***

This stage analyzed the needs of the Project-based Learning-based e-module development process in improving the critical thinking skills of vocational high school students. At this stage, analysis of the curriculum, materials, student characteristics, and analysis of learning outcomes were used. Before development, an analysis of learning conditions was carried out.

***Design***

There were four important steps taken in this stage, such as creating a test, selecting an e-module, selecting a format, and creating an initial prototype of the Project-based Learning-based e-module before coming to the development phase. At this stage, the e-module was also designed for the front page, home login menu, dashboard, module home, material selection, material, practice, evaluation, student profile, and participant score page.

*Front page*

The front page was designed by opening a browser application such as Google Chrome or others, then accessing the e-module link smkn1ivkotoaurmalintang.sch.id. The front page is shown in Figure 2.


Figure 2. Front page display

*Home login menu*

The Login display is a login page where users are asked to enter their username and password before entering the main page. Each student logs in by using the username and password provided by the subject teacher. Users can log in as admin, teacher and student. We can see the home menu login page in Figure 3.


Figure 3. Home menu login

*Dashboard*

The dashboard page display is the page display that is visible after logging in. On this page there is a home menu, e-module tutorial for students, and important links containing teaching materials for vocational and high schools. The dashboard page display can be seen in Figure 4.


Figure 4. Dashboard

*Module home page*

The front page is the page after entering the Digital Communication Simulation course which consists of the introduction and objectives of the e-module, then the technical use of the e-module and Digital Communication Simulation material per chapter. We can see the display in Figure 5.


Figure 5. Module home page

*Material selection page*

This page contains a selection of project material to be carried out, for example Project-based Learning in Basic Competencies (KD), creates and develops written documents using Microsoft Word, as shown in Figure 6.


Figure 6. Material selection page

*Material page*

The material page is an explanation of the material described in the e-module. On this page, there are material explanations, contextual demonstrations, reflections and video tutorials. The menu display for this page is in Figure 7.

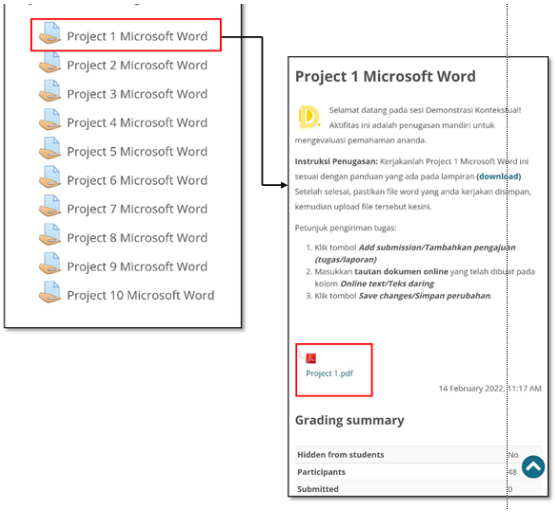


Figure 7. Material page

*Practice page*

This practice page contains exercises from the lesson material consisting of contextual demonstrations and guided reflection. In this page, students can answer practice questions for each KD. The display of this exercise is in Figure 8.


Figure 8. Practice page

*Evaluation page*

The evaluation page in this display contains questions with multiple answers, matching and answers the questions that have been designed. The display of this quiz is in Figure 9.

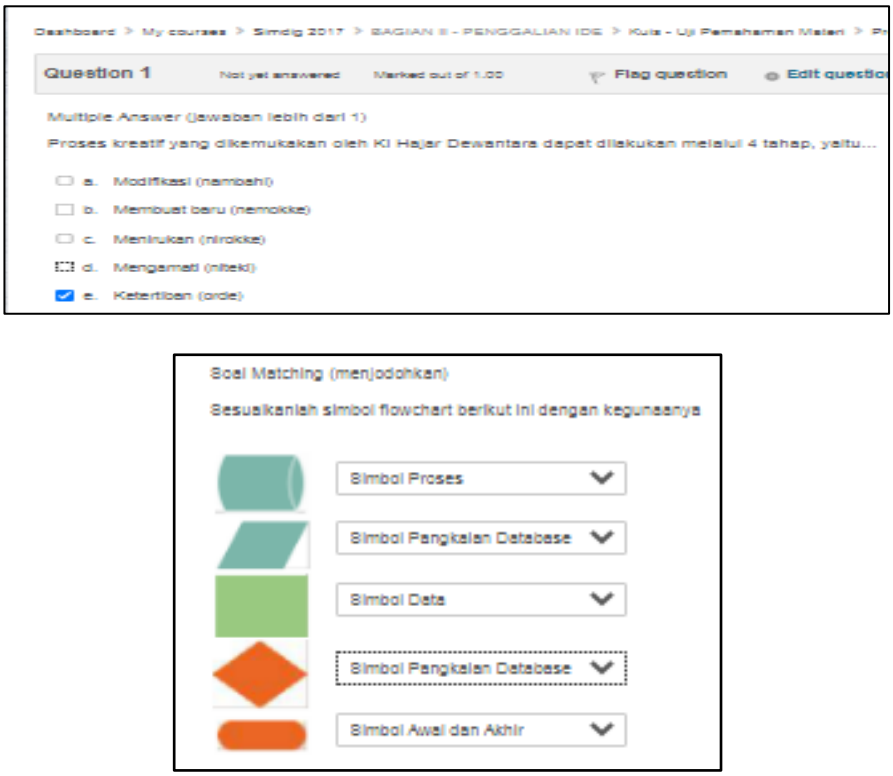


Figure 9. Evaluation page

*Student profile page*

The profile page consists of email, country, privacy, and course information. Then the profile settings include grade, message, preference, and logout. The student profile display is in Figure 10.


Figure 10. Student profile page

*Student grade page*

In this page, there is a display that shows the grades of students who have answered assignments in the reflection, contextual demonstration, and project sections. The grade display is in Figure 11.


Figure 11. Student grade page

### *Develop*

In this stage, three tests were carried out, such as validity tests, practical tests, and effectiveness tests. Products created at the design stage must be validated. This happens when Project-based Learning-based e-module were reviewed and the experts who assessed them provide suggestions for improvement. This study involved two media experts and two material experts who have been teaching for more than ten years and have doctoral degrees, including a professor. Furthermore, practicality testing was carried out at this stage. The aim of the practicality test is to find out how easy it is to use the e-module, how time efficient it is, and how interesting it is for teachers and students to use it when studying. Finally, effectiveness testing was carried out at this stage to determine whether the Project-based Learning-based e-module created is effective in improving students' critical thinking skills.

### *Disseminate*

This disseminate stage was carried out on Project-based Learning-based e-module that have been created. This was done only after the e-module had been validated, tested and stated as valid by

validators and pilots. Initially, questionnaires were distributed to selected students to collect data. Next, a descriptive analysis was performed on the collected data to generate relevant insights. Next, the analysis findings were interpreted and presented in a complete research report. Researchers also prepared scientific papers for publication in international journals. The main aim of this step is to disseminate research results to the scientific community and vocational education practitioners. It is hoped that the development of this project-based e-module will have an impact on other related subjects. Thus, it is hoped that this e-module will improve students' critical thinking skills so that it can contribute to improving overall learning outcomes.

## Participants

Subjects of this research were grade X Computer and Network Engineering (TKJ) students academic year 2021/2022 at SMKN 1 Aur Malintang who enrolled in a simulation and digital communication course. This study has obtained permission from the educational institution with letter number 420.02/0829/PSMK-2022 and the students involved have agreed to be research subjects. This research followed the Declaration of Helsinki which regulated the involvement of humans as research subjects.

## Instruments and data analysis

Table 1 show the Project-based Learning-based e-module assessment indicators used by experts.

Table 1. E-module assessment indicators for validation by experts in media display and content aspects

| Aspect | No. | Indicator |
|---|---|---|
| **Media display** | | |
| | 1 | Font size |
| Display | 2 | Picture and display quality |
| | 3 | Font color |
| | 4 | Operational easiness |
| Media Programming | 5 | Access easiness |
| | 6 | Navigation easiness |
| Utilization | 7 | Benefits for learning process |
| **Content** | | |
| | 1 | The materials match the syllabus |
| | 2 | The materials match the Basic Competences |
| | 3 | The materials match the Lesson Plans |
| | 4 | The materials are clear |
| Learning Materials | 5 | Material completeness |
| | 6 | The materials are understandable |
| | 7 | Independent learning easiness |
| | 8 | Clarity of learning flow |
| | 9 | Suitability of learning videos |
| | 10 | Clarity in writing learning outcomes |
| Learning | 11 | Conformity between the learning achieved and the material |
| | 12 | Different types of information are sent in different ways |
| Summary | 13 | The quality of the summaries in the learning module |

Questionnaires for validation of media display and content were given to material and media experts in the field of simulation and digital communication. Assessment data from experts was analyzed using the V coefficient (Aiken, 1985).

$$V = \frac{S}{[n\,(c-1)]} \quad (1)$$

Description:

s = r-$I_0$
$I_o$ = lowest number for validity rating
c = highest number for validity rating
r = the number that an expert gives

The assessment results in the form of coefficient V from experts were translated into two categories of validation results, valid or invalid, as presented in Table 2.

Table 2. Assessment criteria category

| Coefficient V | Category |
|---|---|
| 0.3– 1.00 | Valid |
| < 0.30 | Invalid |

Next, the e-module was validated. It was continued with implementation and evaluation of practicality tests. This test was carried out on teachers and students. Practicality assessment indicators were as listed in Table 3.

Table 3. Indicators for practicality tests

| Practicality aspect | No | Indicator |
|---|---|---|
| Quality Product | 1 | Media display |
| | 2 | Content accuracy and attractiveness |
| | 3 | Media benefits |
| Presentation of Material | 4 | Material and language accuracy |
| | 5 | Instruction completeness |
| | 6 | Examples and exercises accuracy |
| Utilization | 7 | Simple to use |
| | 8 | Learning process easiness |

To obtain practicality test data, a questionnaire with a 5 point Likert scale was used for assessment. The questionnaire consists of statements related to the practicality of Project-based Learning-based e-module in simulation and digital communication subjects. Teachers and students were given alternative answers including the following:

5 = Very Practical
4 = Practical
3 = Quite Practical
2 = Not Practical
1 = Not Practical

The next step is determining the average value by adding up the values obtained from many indicators and provide practical value with the following Eq. 2.

$$FS = \frac{S}{M}\ x\ 100\% \quad (2)$$

Description:

FS = Final score
S = Score obtained
SM = Maximum score

The level of practicality of the e-module was categorized into 5 levels shown in table 4.

Table 4. E-module practicality category

| Achievement level (%) | Category |
|---|---|
| 85-100 | Highly practical |
| 75-84 | Practical |
| 60-74 | Moderately practical |
| 55-59 | Less practical |
| 0-54 | Not practical |

The next test was a test of the effectiveness of e-module based on Project-based Learning which involved 25 students. The learning results were compared using One Group Pretest-Posttest Design. The effectiveness test was carried out using a paired T test.

Table 5. One group pretest-posttest design

| Pretest | Treatment | Posttest |
|---|---|---|
| Q1 | X | Q2 |

Description:

Q1 : Pretest before treatment is given
X : Treatment (Implementation of PjBL-based learning e-module)
Q2 : Posttest after the treatment is given

## 3. Results

### Validity of e-module

Based on the average score from media display and content or media experts, this e-module was categorized as valid. Table 6 show that the quality of the e-module was considered valid and suitable to use from the perspective of e-module experts and material experts.

Table 6. Media display and material expert validation results

| No. | Validation Aspect | Aiken's V | Category |
|---|---|---|---|
| **Media** | | | |
| 1. | Display | 0.81 | Valid |
| 2. | Media Programming | 0.83 | Valid |
| 3. | Utilization | 0.81 | Valid |
| | **Average** | **0.82** | **Valid** |
| **Material** | | | |
| 1. | Material Aspects | 0.83 | Valid |
| 2. | Learning Aspects | 0.84 | Valid |
| 3. | Summary Aspects | 0.83 | Valid |
| | **Average** | **0.84** | **Valid** |

## Practicality of e-module

The results of data analysis from the questionnaire filled out by the teacher shows that the practicality value of the e-module is 89%, which shows that this e-module is very practical in the teacher's view. Apart from that, data from the questionnaire filled out by students shows an overall practicality value of the e-module of 84.07%, which shows that this e-module is considered practical by students. A graph showing the level of practicality of the e-module based on teacher and student responses can be seen in Figure 12.

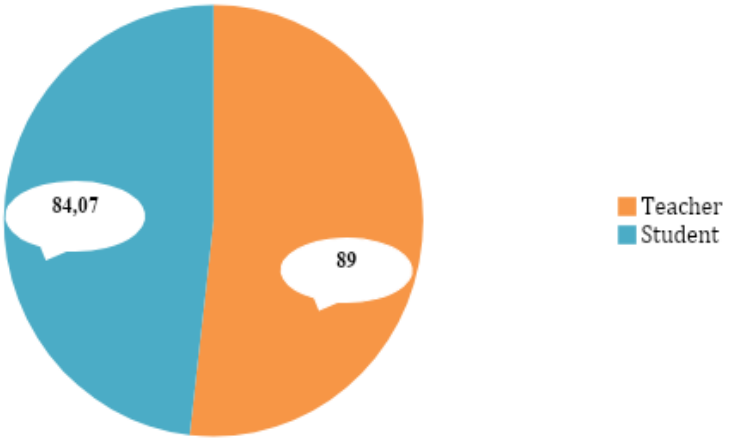


Figure 12. Results of teacher and student practicality assessments

## Effectivity

Data analysis in Table 8 shows that the mean is 71.20 with a standard deviation of 14.089 and a standard error of the mean of 2.818, while for the post-test results the mean is 85.40 with a standard deviation of 11.358 and a standard error of the mean of 2.272. Descriptively, it is found that the average score for learning outcomes in the Pre-Test (71.20) is lower than the post-test score (85.40). This shows that there is a descriptive difference in scores between the pre test and post test. These results concluded that students after using e-module based on Project-based Learning showed improvements in the learning process.

Table 7. Student PreTest and PostTest results

| Paired Samples Statistics | | | | | |
|---|---|---|---|---|---|
| | | Mean | N | Std. Deviation | Std. Error Mean |
| Pair 1 | PreTest | 71.20 | 25 | 14.089 | 2.818 |
| | PosTest | 85.40 | 25 | 11.358 | 2.272 |

Table 8 explains the results of the correlation test between PreTest variables and PostTest variables. The correlation coefficient value is obtained at 0.863 with a significance value (Sig.) of 0.000. Due to the Sig value. 0.000 < probability 0.05, then there is a correlation between the PreTest variable and the PostTest variable. This is also supported by the results in Table 9 which show a significant value in the correlation between the pre test and post test.

Table 8. Correlation results between PreTest and PostTest

| Paired samples correlations | | | | |
|---|---|---|---|---|
| | | N | Correlation | Sig. |
| Pair 1 | PreTest & PosTest | 25 | .863 | .000 |

To determine whether the difference in mean pre-test and post-test scores is significant, the results of the paired T test can be referred to (Table 9). Table 11 Paired Samples Test output, known Sig value. (2-tailed) is 0.000 < 0.05, so the difference in mean value between the pre test and post test is significant. This shows that there is an influence on learning outcomes using e-module based on Project-based Learning in improving learning outcomes in simulation and digital communication subjects.

Table 9. Output paired samples test

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | PreTest PosTest | -14.200 | 7.171 | 1.434 | -17.160 | -11.240 | -9.902 | 24 | .000 |

From the Paired Samples Test output table in table 9, the Mean Paired Differences value is -15,400. This value shows the difference between the average PreTest learning results and the average PostTest learning results or 71.20 - 85.40 = -14,200 and the difference is between -17,160 to -11,240 (95% Confidence Interval of the Difference Lower and Upper).

## 4. Discussion

The Moodle application facilitates the creation of e-module with additional features such as animation, music and videos, making them more interesting and effective as learning media. E-module simulation and digital communication based on Project-based Learning to improve Critical Thinking Skills in vocational high schools is an alternative learning resource that can be applied online, blended learning, or in the classroom (Yusri et al., 2024). In this study, the e-module was rated as valid by media display experts (82%) and content or material experts (84%). This finding

is in line with the study of Hadiyanti et al. (2021), which developed an e-module on sets material with a valid category. The development of this e-module offers innovation as well as a challenge for teachers or lecturers to teach with variety models (Wijayanto et al., 2023).

Teachers who do not adapt to information technology development tend to stagnate, do not try new things, and only rely on books provided by the government. On the other hand, innovations in technology and information can become practical tools for learning, both online and face-to-face, such as electronic whiteboards and electronic modules (Maksum & Purwanto, 2022). Therefore, e-module must be designed with rich activities and clear instructions so that students can learn independently.

Based on the practicality assessment by the teacher in charge of simulation and digital communication subjects, the e-module developed was assessed as practical with a score of 89.00%, which indicates highly practical. The analysis results from the student questionnaire show that the overall practicality value of the e-module is 84.07%, which indicates a good level of practicality (Asrizal et al., 2024). This e-module has been proven to be practical and can be used anytime and anywhere as innovative teaching material (Mardiyah et al., 2020). The e-module developed based on indicators of critical thinking skills received a positive response from students, where 25 students who used this e-module achieved learning completion.

## 5. Conclusion

This study has developed an e-module that has been assessed by media display experts and content or material experts and stated as valid. The e-module has also been rated as highly practical according to teacher assessment and practical according to student assessment. The evaluation results show that students' scores after using the e-module are higher than the scores before using the e-module which indicates the effectiveness of the e-module in improving critical thinking skills and theoretical understanding. This study implies that technology in vocational high school learning can significantly improve students' skills and learning outcomes. E-module design with interactive features such as animation, video, and audio can make abstract subject material more concrete and interesting, and support the mastery of non-technical skills that are important in the 21st century. Therefore, vocational high schools are recommended to integrate e-module based on Project-based Learning using technology in their curriculum to prepare students with relevant skills for the world of work. This study provides recommendations to teachers in designing vocational high school curriculum to integrate e-module in learning so that students can master soft skills and hard skills. Educators must also continue to develop creativity and innovation in their teaching methodology. Training on the use of the latest technology in education can help teachers create more engaging and effective learning environments. Further research is needed to test the effectiveness of e-module in various educational contexts and fields of study and to improve e-module based on user feedback. Apart from e-module, other technologies such as online learning platforms and mobile applications should also be considered to enhance students' learning experience and ensure their readiness to face the challenges of the 21st century.

## Author contribution

Rifmelda Rizal: developed the methodology, conducted the investigation, and wrote the original manuscript; Ganefri: supervised the research, provided resources, and contributed to writing the original manuscript; Ambiyar: analyzed data, and revised the manuscript.

## Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## Acknowledgements

The authors would like to thank all parties who have assisted in the research

## Conflict of interest

The authors declare no conflict of interest.

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