E-Modules for Computer Network Practicum Based on Problem-Based Learning and Peer Tutoring: A Practical Solution to Develop 21st-Century Skills

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A B S T R A K

Pembelajaran di era Revolusi Industri Keempat memerlukan inovasi dalam pembelajaran, salah satunya melalui media pembelajaran. Modul E merupakan media pembelajaran yang lebih efisien dan fleksibel dibandingkan media konvensional. E-modul yang diintegrasikan dengan model pembelajaran yang tepat dapat membantu mencapai hasil belajar yang optimal. Penelitian ini bertujuan untuk mengembangkan modul elektronik (e-modul) Praktikum Jaringan Komputer berbasis Problem Based Learning (PBL) dan Peer Tutoring (PT) serta menguji efektivitasnya dalam meningkatkan keterampilan abad 21 pada mahasiswa. Metode penelitian yang diterapkan adalah Research and Development (R&D), dengan validitas dan praktikalitas modul yang dinilai oleh ahli dan mahasiswa. Uji efektivitas dilakukan dengan membandingkan hasil post-test antara kelompok eksperimen yang menggunakan e-modul PBL dan PT dengan kelompok kontrol yang menggunakan LKS konvensional. Temuan penelitian menunjukkan bahwa e-modul yang dikembangkan memiliki validitas yang kuat, mudah diterapkan, dan efektif dalam meningkatkan keterampilan abad 21 pada siswa. Hasil post-test kelompok eksperimen juga jauh lebih tinggi dibandingkan kelompok kontrol. Implikasi penelitian ini adalah memberikan kontribusi yang signifikan terhadap pengembangan bahan ajar berbasis teknologi untuk meningkatkan kualitas pembelajaran praktikum jaringan komputer. Penerapan strategi PBL dan PT dalam e-modul dapat menjadi alternatif efektif dalam merancang bahan ajar yang berorientasi pada pengembangan keterampilan abad 21, menjadi panduan bagi pendidik dan pengembang kurikulum untuk meningkatkan pendekatan pembelajaran inovatif di berbagai mata pelajaran.

A B S T R A C T

Learning in the era of the Fourth Industrial Revolution requires innovation in learning, one of which is through learning media. E module is a learning media that is more efficient and flexible than conventional media. E-modules that are integrated with appropriate learning models can help achieve optimal learning outcomes. This research aims to develop an electronic module (e-module) for Computer Network Practicum based on Problem-Based Learning (PBL) and Peer Tutoring (PT) and test its effectiveness in enhancing 21st-century skills among students. The research method applied is Research and Development (R&D), with module validity and practicality evaluated by experts and students. Effectiveness testing is conducted by comparing post-test results between the experimental group using PBL and PT e-modules and the control group using conventional worksheets. The research findings indicate that the developed e-module has strong validity, is easy to implement, and is effective in improving 21st-century skills among students. The post-test results of the experimental group are also significantly higher than those of the control group. The implications of this research are significant contributions to the development of technology-based teaching materials to enhance the quality of computer network practicum learning. The implementation of PBL and PT strategies in the e-module can be an effective alternative in designing teaching materials oriented towards the development of 21st-century skills, serving as a guide for educators and curriculum developers to enhance innovative learning approaches across various subjects.

1. INTRODUCTION

An exemplary learning resource must fulfill several criteria, including user-friendliness, aesthetic appeal, providing students with a meaningful learning experience, and ultimately enhancing learning outcomes. To optimize learning outcomes, the developed media should be meticulously crafted, with a particular focus on the content and learning materials (Jain & Jain, 2022; Williams & Beam, 2019). Achieving this requires strict adherence to the specified learning objectives, ensuring that the educational content aligns seamlessly with the intended goals. The teaching materials and learning resources in the era of Learning 5.0 exhibit remarkable diversity. Among the myriad options are case-based modules, problem-based modules, electronic modules (e-

modules), augmented reality modules, and virtual reality modules (Sriarunrasmee et al., 2015; Sułkowski et al., 2021). In the context of the computer network practicum course at Universitas Negeri Padang, the learning process is facilitated by laboratory facilities. However, there is a recognized need to upgrade the technology and content of the practical modules. A notable transition is observed, shifting from traditional paper-based practical courses to modern, electronic-based formats (Anwar & Wibawa, 2019; Nortvig et al., 2018). This adaptation aims to enhance the overall learning experience and align the course with contemporary educational advancements. Learning in the era of the Fourth Industrial Revolution (Industrial Revolution 4.0) is an essential component of 21st-century education. Education during this revolutionary period involves the seamless integration of technology into the learning process (Kamruzzaman et al., 2023; Simsek & Can, 2020). In the context of the Fourth Industrial Revolution, the anticipated outcomes of learning extend beyond the acquisition of both hard and soft skills. The soft skills in question are the 4Cs: critical thinking, creativity, collaboration, and communication (Alenezi, 2020; Lampropoulos et al., 2019). Hard and soft skills constitute integral components of the learning outcomes within the educational process. These outcomes serve as the foundation for assessing the attainment of learning objectives. A recurring issue is the suboptimal realization of learning outcomes in higher education.

An initiative to enhance students' hard and soft skills and achieve optimal learning outcomes involves adopting student-centered learning. This approach is particularly well-suited for addressing the intricacies of 21st-century Learning 4.0 (Astuti et al., 2021; Irving, 2006). However, the prevailing reality indicates that teacher-centered education remains prevalent among lecturers. The learning process often concentrates solely on hard skills, neglecting the development of students' soft skills, especially in practical courses. obtained grades below the acceptable criteria in the Computer Network Practicum course. Subsequent observation identified external factors influencing students' learning outcomes, specifically in the Computer Network Practicum course, with learning media emerging as a significant contributor. Learning media serves as an intermediary, facilitating the delivery of messages or information between the instructional material source and the learners, ultimately aiming to impart effective instruction (Anggeraini, 2018; Irawaty et al., 2021).

Numerous research journals have examined the influence of smartphones on our lives, consistently highlighting their positive impact. Smartphones offer myriad conveniences in daily activities, serving as valuable tools for work, learning, and communication (Dopo & Ismaniati, 2016; Sefriani & Sepriana, 2022). This transformative influence has reshaped lifestyles, leveraging smartphones to enhance convenience and efficiency, particularly in the realm of education. The learning process has evolved to accommodate these changes, with innovations like the utilization of e-modules emerging as a solution to enhance and enrich the overall learning experience (Albana & Sujarwo, 2021; Apriani et al., 2021). E-modules, electronic learning modules accessible anytime and anywhere without the need for additional applications on personal devices like computers or laptops, offer numerous advantages. These modules integrate diverse learning content, including video, audio, and images, enhancing students' comprehension of the material. E-modules emerge as an effective alternative for educators to deliver learning materials in various settings, whether online or face-to-face. Their flexibility allows learners to enhance their understanding of presented materials, contributing to a more dynamic and engaging learning experience (Elshami et al., 2021; Islam et al., 2022).

A learning model that can help achieve optimal learning outcomes is student-centered learning. Two examples of learning models that fall into this category are problem-based learning (PBL) and Peer Tutoring. PBL is a learning model that uses projects as a tool for learning. Project tasks can be completed in groups (Aji et al., 2018; Ulger, 2018). Peer Tutoring is learning that is done by classmates who have more ability to help their friends understand concepts or perform activities. Peer Tutoring ensures that each group consists of students with different levels of ability and knowledge (Miravet et al., 2014; Sytsma et al., 2019).

Problem-Based Learning (PBL) serves as a model designed to cultivate critical thinking, problem-solving, and self-regulation skills. Central to this approach is the use of authentic problems as the focal point of the learning process. Collaborative learning within groups has been shown to yield better learning outcomes compared to individual learning. Through PBL, students engage in a more interactive and practical educational experience, fostering a deeper understanding of the subject matter and honing essential skills for real-world problem-solving (Fajri et al., 2021; Huang et al., 2019). PBL aims to develop critical thinking patterns in solving problems and mastery of learning materials (Deveci & Nunn, 2018). In the problem-based learning model, students can analyze, test, make references, and conclude by investigating the problem. This learning model is considered adequate because students can find solutions and solve problems independently to increase concept understanding. Meanwhile, peer tutoring is a learning model that allows more advanced students to help other students in the same class (Thurston et al., 2020; Ullah et al., 2018). This learning model is considered effective because students can find solutions and solve problems by themselves to increase their understanding of concepts. Therefore this study aims to develop an electronic module (e-module) for Computer Network Practicum based on Problem-Based Learning (PBL) and Peer Tutoring (PT) and test its effectiveness in enhancing 21st-century skills among students.

2. METHOD

This research employs the Research and Development (R&D) or Educational Design Research development model, a systematic approach for creating or enhancing educational products. R&D involves a series of steps aimed at developing new products or improving existing ones (Sugiyono, 2019). The model is crucial in conveying information efficiently and is often selected based on the specific requirements of the research. In this case, the research adopts the ADDIE model, encompassing Analysis, Design, Development, Implementation, and Evaluation stages (Widyastuti, 2019). The Analysis stage focuses on understanding the needs for learning module development. This involves a comprehensive analysis of requirements, including needs analysis, student analysis, and curriculum analysis/Semester Learning Plan (RPS). To gather information, a needs analysis questionnaire was distributed to 30 students, designed to assess their opinions on the E-module, particularly in the Computer Networks Practicum course. The questionnaire, consisting of 40 questions comparing current conditions and expectations, aimed to filter insights crucial for E-module development. Moving to the Design stage, it builds upon the analysis results from the previous stage. This involves determining the essential components of the e-module, such as creating a concept map of the material and collecting references for development. The Design stage lays the foundation for the subsequent development process, ensuring a structured and well-prepared approach to crafting the e-module. In development stagem, the instruments and instrument grids used during the validation process of the e-module development encompassed various aspects, ensuring a comprehensive evaluation. These instruments were meticulously designed during the earlier stages of planning. The assessment focused on four key aspects: media, content, language, and interface.

The instrument grids provided a structured framework for validators to assign scores and provide qualitative feedback for each aspect. The grids likely included specific criteria, rating scales, and space for comments. Validators used these grids as a systematic guide to assess the e-module's development, offering constructive feedback and recommendations for improvement. The comprehensive evaluation based on these instruments ensured the refinement of the e-module for optimal educational effectiveness. The fourth stage of this research is the implementation phase, during which students enrolled in the Computer Network Practicum course will engage in learning using the developed e-modules. Researchers will carefully observe and document the learning process on observation sheets to identify areas for improvement in the e-module. Following the completion of the learning activities, students will undergo an assessment using provided questions to gauge the effectiveness of the three modules developed, aligning with the learning outcome indicators. The final stage is the evaluation, where the developed e-module undergoes refinement based on insights gathered from observation sheet notes and questionnaires. Various evaluation instruments are employed, including questionnaires for students, pretests, post-tests, and observation sheets assessing student performance. These instruments serve as valuable tools in comprehensively assessing the impact and effectiveness of the e-module in enhancing the learning experience for students in the Computer Network Practicum course.

3. RESULT AND DISCUSSION

Result

The value of the seven components in the validated RPS is 0.885 with valid criteria is presented in Tabel 1.

Table 1. RPS Validation Results

No.	RPS Components	Validator1 Score	Validator 2 Score	Validator 3 Score	Average	Description
1	Learning Outcomes	0.870	0.880	0.850	0.867	Valid
2	Course Description	0.895	0.910	0.946	0.917	Valid
3	Learning Materials	0.795	0.810	0.799	0.801	Valid
4	Learning Resources	0.910	0.925	0.898	0.911	Valid
5	Learning Media	0.930	0.900	0.878	0.903	Valid
6	Learning Activities	0.880	0.896	0.915	0.897	Valid
7	Assessment	0.900	0.911	0.890	0.900	Valid
Average Score					**0.885**	**Valid**

Base on Table 1, valid means that the components of the formulation of learning outcomes, course descriptions, selection of learning materials, selection of learning resources, the section of learning media, learning activities, and assessment design are compiled completely and follow learning needs to achieve the expected learning outcomes.

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The development of e-modules based on problem-based learning and peer tutoring was validated by experts, namely content expert lecturers (course lecturers), presentation expert lecturers, and language expert lecturers. The validation aims to measure e-module learning as a good quality e-module from reliability in developing problem-solving skills, content, presentation, and language. The results of the e-module validation are illustrated in Table 2 and Table 3.

Table 2. Media Expert Validation Data

No.	Aspects	Validator 1 Score1	Validator 2 Score	Validator 3 Score	Validator 4 Score	Score	Criteria
1	Media Aspects	0.880	0.870	0.880	0.850	0.870	Valid
2	Content Aspect	0.896	0.895	0.910	0.946	0.912	Valid
3	LanguageAspect	0.915	0.795	0.810	0.799	0.830	Valid
4	Interface Aspects	0.900	0.910	0.925	0.898	0.908	Valid
5	Functional Aspects	0.911	0.930	0.900	0.878	0.905	Valid
	Total Value					**0.885**	**Valid**

Table 3. Material Expert Validation Data

No.	Aspects	Validator 1 Score	Validator 2 Score	Validator 3 Score	Validator 4 Score	Score	Criteria
1	Content Aspect	0.897	0.912	0.850	0.880	0.885	Valid
2	Construction Aspect	0.881	0.870	0.920	0.900	0.893	Valid
3.	Problem Solving Aspect	0.901	0.880	0.875	0.910	0.891	Valid
4.	Peer Tutoring Aspects	0.878	0.911	0.900	0.898	0.897	Valid
	Total Value					**0.892**	**Valid**

The e- module practicality assessment results can be seen in Table 4.

Table 4. Practicality Validation Data

No.	Respondents	Percentage (%)	Category
1.	M1	94.67%	Very Practical
2.	M2	69.33%	Practical enough
3.	M3	81.33%	Practical
4.	M4	84.00%	Practical
5.	M5	76.00%	Practical enough
6.	M6	80.00%	Practical
7.	M7	89.33%	Very Practical
8.	M8	72.00%	Practical enough
9.	M9	73.33%	Practical enough
10.	M10	96.00%	Very Practical
11.	M11	93.00%	Very Practical
12.	M12	77.00%	Practical enough
	Average	**82.00%**	**Practical**

The results of the e-module effectiveness assessment can be seen in Table 5.

Table 5. Effectiveness Result Data

No.	Student	Percent Value	Classification Results
1.	Student 1	60%	Simply
2.	Student 2	80%	Good
3.	Student 3	70%	Very good
4.	Student 4	60%	Less
5.	Student 5	60%	Simply
6.	Student 6	60%	Less
7.	Student 7	70%	Good
8.	Student 8	70%	Very good
9.	Student 9	80%	Good

No.	Student	Percent Value	Classification Results
10.	Student 10	60%	Simply
11.	Student 11	70%	Good
12.	Student 12	60%	Very good
Achievements		**66.67%**	**Good**

The implementation of the e-module that has been developed is carried out for students who take the Computer Network Practicum course. There are two classes in this study, namely, the experimental class and the control class. The results of the e-module implementation were obtained using previously prepared instruments. The e-module implementation was carried out in the experimental class using the Research and Development (R&D)method. The implementation results can be seen from the pretest and post-test results shown in Table 6.

Table 6. Table of Pretest and Post-test Results

Research Subject	Average Pretest Score	Average Posttest Score
Experiment Class	57.40	83.19
Control Class	58.80	69.20

Discussion

The initial stage of this research involves conducting field and literature studies. Through these studies, researchers gather data from the field and existing literature. The collected data is then meticulously analyzed to identify fundamental problems. In the needs analysis conducted on students enrolled in the Computer Network Practicum course, it was determined that (1) students require learning media that supports independent learning, facilitating study sessions anywhere and anytime without the need for constant lecturer supervision, and (2) they prefer media that is engaging, interactive, and eco-friendly (paperless) (Almomen et al., 2016; Rejekiningsih et al., 2021). Furthermore, the data from this stage includes insights into student needs, revealing (1) diverse educational backgrounds, encompassing graduates from High School, Vocational High School, and Islamic Boarding School, (2) possession of smartphones without any hindrances in operation, and (3) commendable student learning motivation. This comprehensive analysis forms the basis for addressing the identified needs and tailoring the subsequent stages of the research to meet the specific requirements of the students in the Computer Network Practicum course (Bichi, 2016; Johansson, 2020).

During this stage, concept analysis is conducted to systematically and comprehensively identify concepts within the Network and Computer Practicum course lectures. This analysis is aligned with the Semester Learning Plan (RPS) of the course, outlining specific learning outcomes to be achieved. These outcomes encompass various topics such as Computer Hardware Identification and Installation, BIOS Computer Network Media Installation, IP address management, Subnetting, Supernetting, Variable Length Subnet Mask (VLSM), and Static Routing. The formulation of learning outcomes adheres to the Semester Learning Plan (RPS) and is divided into two components: hard skills and soft skills (Agung et al., 2022; Ekayana et al., 2021). Hard skills focus on students' abilities to construct computer networks, engage in continuous network management, and master the fundamental principles of computer network systems, particularly in developing local network-based systems. On the other hand, soft skills emphasize students' critical thinking, problem identification, and comprehensive problem-solving abilities. They are expected to make informed decisions based on thorough analysis and data evaluation. This dual-component approach ensures a holistic development of students' skills in both technical and interpersonal domains (Levy, 2015; Rasheed et al., 2020).

Based on the needs analysis, understanding of students, and conceptual considerations, the development of problem-based learning-oriented e-modules and peer tutoring has been deemed essential to enhance both hard skills and soft skills among students. The e-modules serve as learning media, fostering independent learning opportunities anywhere and anytime (Dopo & Ismaniati, 2016; Nugraha, 2018). The validation of the Semester Learning Plan (RPS) encompasses various components, including learning outcomes, course descriptions, learning materials, resources, teaching media, activities, and assessments. The RPS validation involved multiple expert validators.

The developed e-module adopts an instructional approach that introduces material complexities at the outset, presenting practicum questions for collaborative problem-solving within groups (peer tutoring). This design aims to enhance students' problem-solving skills in the context of industrial 4.0 learning (Hui et al., 2021; Sujanem et al., 2020). A practicality test was executed to assess the user-friendliness of the e-module, involving a questionnaire administered to students enrolled in the Computer Network Practicum course, both in the experimental and control groups. The results of the practicality assessment, indicate an 82% practicality rating, categorized as practical. To evaluate the effectiveness of the e-module development trial, an effectiveness test was conducted, measuring the success rate of students in answering questions. The data for the effectiveness test were

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derived from students enrolled in the Computer Network Practicum course, encompassing both the experimental and control groups. The effectiveness assessment outcomes reveal a 66.67% effectiveness rating, categorized as good. These findings suggest that the developed e-module exhibits practicality and effectiveness, signifying its potential as a valuable learning resource for the Computer Network Practicum course.

The research data calculations affirm that the development of the Computer Network Practicum e-modules falls within the valid category. According to media experts, the achieved value is 0.855, signifying a good category. Material experts assessed the value at 0.892, indicating that the developed media is suitable for the Computer Network Practicum learning process. Regarding practicality, the Computer Network Practicum e-module was rated in the convenient category, with a percentage value of 82.00%, signifying ease of use in the learning process (Santosa et al., 2017; Wu & Nian, 2021). Moreover, the Computer Network Practicum learning e-module proved more effective than the existing conventional lab sheet media, as evidenced by the higher final score (post-test) of the experimental class (83.19) compared to the control class (69.20).

The study's findings underscore the significance of learning media as a tool for enhancing instruction and achieving educational objectives with efficiency and clarity. A conducive learning environment, coupled with high-quality resources and media, is essential for effective learning (Anggraini et al., 2017; Karima et al., 2021; Sağlam & Sert, 2012). The selection of media for instruction should consider various factors such as course features, learning objectives, learning styles, facilities, and infrastructure. These factors should guide the careful selection of media to ensure alignment with educational activities. As emphasized by previous study certain factors must be considered when choosing educational materials (Ivanović et al., 2013).

In conclusion, the learning e-modules developed in this study demonstrate validity and reliability as learning media. The instruments utilized in the study are deemed appropriate and reliable for measuring the validity, practicality, and effectiveness of the developed e-modules. The implications of this study have important contributions for the development of technology-based learning resources that will improve the quality of computer network practicum learning. The e-module's application of Problem Based Learning and Peer Teaching strategies can be a useful substitute when creating learning materials focused on the development of 21st-century skills. This can act as a roadmap for lecturer and curriculum developers to improve innovative and creative learning methods in a range of subject areas.

4. CONCLUSION

Based on the outcomes and discussions of this research, it can be deduced that the e-module, structured around problem-based learning and peer tutoring, has demonstrated validity, effectiveness, and practicality in enhancing students' knowledge and skills in the Computer Network Practicum course. The validation by subject matter experts and media validation affirms the e-module's eligibility concerning content, structure, problem-solving, and peer tutoring. Moreover, the practicality test results indicate that the e-module is user-friendly, as evidenced by the positive responses from student questionnaires. Beyond its validity and practicality, e-modules based on problem-based learning and peer tutoring prove to be more effective in enhancing students' knowledge and skills compared to traditional lab sheets. This is evident in the higher average post-test scores of the experimental class compared to the control class. Hence, the Computer Network Practicum e-module, employing problem-based learning and peer tutoring, holds the potential to nurture 21st-century skills and is applicable in the era of Industry 4.0 learning. In the context of Indonesia, where class sizes are often large, and there is a shortage of educators, problem-based learning and peer tutoring emerge as a viable and relevant alternative learning model.

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