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Development of a Biochemistry Practical E-Module Using a Project-Based Learning Model to Improve Students' Creative Thinking Skills

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ABSTRACT

This research and development (R&D) study aims to assess the validity, practicality, and effectiveness of the Android-based E-Module for Biochemistry Practicum developed using Construct 2. The development of this E-Module is designed to improve students' creative thinking skills. This study adopted the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The research sample consisted of 27 students from the Chemistry Education Study Program, FKIP ULM Banjarmasin, Class of 2019, Class A1. The data collection methods used were test and non-test methods. The research instruments used for data collection in this analysis include essay assessments (pre-test and post-test) and questionnaires. Data analysis was conducted to measure three main aspects: validity, practicality, and effectiveness. The results showed that the developed E-Module product met all criteria: (1) Highly Valid, based on expert assessment of general aspects, content, language, and media design; (2) Highly Practical, as evidenced by the results of individual and small group trials, student and teaching assistant response questionnaires, and observation sheets; (3) Highly Effective, as indicated by the N-gain scores for students' creative thinking skills, which fall into the High category. Overall, this Android-based Project-Based Learning (PjBL) Biochemistry Practical E-Module has proven to be suitable and effective as a learning medium to enhance students' creative thinking skills.

INTRODUCTION

The Chemistry Education Study Program of the Faculty of Teacher Training and Education, University of Lambung Mangkurat aims to produce Bachelor of Education graduates with various competencies to serve as educational administrators, laboratory supervisors, research assistants, and entrepreneurial innovators. One essential course is the Biochemistry Practicum in the 6th semester (Even). This course equips students to create simple fermentation biotechnology products and to test their quality precisely and correctly, in accordance with the course learning outcomes. The materials covered, such as the enzymatic production of bioethanol from peatland biomass or Virgin Coconut Oil (VCO), require students to meet specific performance indicators, including project planning, use of tools and materials, implementation, evaluation of report quality, primary literature review, and presentation skills.

Students in the 21st century require Learning and Innovation competencies that cover four dimensions: critical analysis, inventive thinking, cooperative engagement, and effective communication. These competencies are summarized under creative thinking skills (Ekaputra & Widarwati, 2023). These skills, especially creativity and innovation, are essential provisions

for navigating the world of work in the era of Society 5.0 (Taufiqurrahman, 2023). The lack of learning innovation that does not accommodate the development of this dimension will produce graduates who are unable to create fresh ideas, lack skills in solving complex problems, and are unprepared to meet the demands of work adaptation. The latest PISA results even emphasize this urgency, showing that only 30.43% of students are proficient in formulating creative solutions (Simanjuntak & Saragih, 2025). This data clearly highlights the urgent need for educational reform to prepare graduates to meet the demands of the 21st-century workforce.

Several studies have shown that students' creative thinking skills remain relatively low, primarily because practical learning tends to be centered on lecturers or assistants. Consequently, students are less involved in complex problem-solving, which in turn reduces their interest in exploring various strategies (Firdaus et al., 2021). This situation is exacerbated by conventional methods where the lecturer is the sole authoritative source, encouraging students to memorize rather than understand concepts and develop analytical thinking skills (Kanthimathi & Raja, 2025). A direct consequence of this condition is the low achievement of course learning outcomes (CLOs), which should require mastery of higher-order thinking skills.

The results of the needs analysis using an observation questionnaire showed that the media currently used (printed books) were considered less interesting and less effective at increasing student creativity (33.3%). Therefore, additional learning media are needed for Biochemistry practicums. The ideal press, as agreed by students (66.7%), is interactive media based on the Android platform, a format they are not yet familiar with, such as Construct 2, to foster their creativity and engagement. The use of media via smartphones for practicum activities is currently still minimal, even though interactive media such as digital worksheets can increase student activity and creativity skills (Ekaputra & Hasanah, 2021). In addition, digital media facilitates easier learning and can be accessed anywhere (Ekaputra, 2020).

Current technological developments open up opportunities to utilize information and communication in education, one of which is the development of E-Modules. These digital modules are instructional units that can be accessed through various electronic platforms, including laptops and Android devices (Mentu R. M. et al., 2022). However, the rise of games and social media (such as TikTok) actually creates challenges, because students tend to grasp entertainment content more quickly than lecture concepts (Audhiha et al., 2022). Therefore, renewal and innovation in media and learning models are needed (Muthoharoh C., 2021). An innovative solution that can be used is Construct 2 software, which is recognized as an interactive and educational learning medium (Priyatna & Wiguna, 2020). Construct 2, as an HTML5-based application platform, offers an easy-to-use interface similar to office software, making it an ideal choice for developing interactive media that supports learning models in higher education (Putra et al., 2022; Putri D. et al., 2021).

Project-Based Learning (PBL) is a recognized practical approach to developing students' creative thinking skills (Ekaputra, 2024). PjBL encourages students' independent activities, where they gather knowledge to produce valuable products, while simultaneously practicing original thinking, inventive methods, and creative problem solving (Prasetyo et al., 2021). With PjBL, students can concentrate on completing projects without neglecting course objectives, improving their ability to utilize technology to produce and deliver work, and ultimately becoming more creative (Dewi, 2021). Departing from this urgency, this study adopts PjBL and E-Modules with a dual focus on developing valid and feasible E-Modules and testing their effectiveness in measuring significant improvements in 21st-century students' creative thinking skills in the Biochemistry Practicum course.

METHOD

Research Design

This research is a type of " Research and Development " research. The research design uses five stages of the ADDIE model, which consist of (1) Analysis, (2) Design, (3) Develop, (4) Implement, and (5) Evaluate. The results of the research include validation data (product validity, evaluation question validity, and learning device validity), practicality data, and effectiveness data. The development carried out is a biochemistry practicum E-Module using an Android-based PjBL model with software Construct 2 to improve creative thinking skills in biochemistry practical courses (Branch, 2010).

Research Target

This study used a sample of 27 Chemistry Education students from Lambung Mangkurat University, class A1, enrolled in the biochemistry practicum course, to assess improvements in students' creative thinking skills using the PjBL learning model.

Research Data

The data collection technique in this study was to determine the level of validity, practicality, and effectiveness of the biochemistry practicum e-module using PjBL in improving students' creative thinking skills. The data collection methods used were test and non-test methods. The non-test method was used to determine students' needs, the validity, and the practicality of using the e-module. The test method was used to determine students' creative thinking skills.

Research Instruments

The research instruments used for data collection in this analysis include essay assessments (pre-test and post-test) intended to measure creative cognitive abilities, media validation assessments, feedback questionnaires from students and assistant practitioners, and readability evaluations of individual and small-group assessments, as well as observational data sheets. (Pursitasari et al., 2022). Media validation assessments assess the suitability of general, content, language, and media design aspects. Feedback questionnaires from students and practitioners are used to assess satisfaction with the use of the biochemistry practicum E-Module. Readability evaluations are conducted to assess students' practicality in using the E-Module in biochemistry practicum courses. Observers will assess observational data sheets during the biochemistry practicum activity process at the PjBL stage.

Data analysis

Data analysis was conducted to measure three main aspects: validity, practicality, and effectiveness. Validity of the practical E-Module biochemistry, data analysis is carried out based on expert criteria scores (validators) who assess the suitability of the product, where the results will be compared with the criteria standards presented in Table 1 below:

Table 1. Validity Criteria for the Biochemistry Practical E-Module

Percentage (%)	Criteria	Information
85-100	Very Valid	No Revision Needed
70-<85	Valid	No Revision Needed
50-<70	Less Valid	Minor Revision
0-<50	Invalid	Major Revision

(Retnawati, 2020).

Practicality analysis Practical E-Module biochemistry done through a series of tests, namely readability tests (individual and small group trials), response tests (questionnaires),

students and lab assistants, as well as observations (sheets observation of the laboratory assistant's abilities in using E-Modules and student skills) . The collected data were then analyzed using *Likert* scale scoring, and the results of the practicality percentage were compared with the standard criteria presented in Table 2 below:

Table 2. Practicality Assessment Criteria

Percentage (%)	Criteria
81-100	Very Practical
61-80	Practical
41-60	Quite Practical
21-40	Less practical
0-20	Impractical

(Aldilla & Usmeldi, 2024)

The analysis of the research's effectiveness is based on the N-gain calculation of the creative thinking skills test results, which measures the level of improvement in these skills. The test results are then converted using the creative thinking percentage guidelines presented in Table 3 below:

Table 3. Creative Thinking Percentage Conversion Guidelines

Percentage (%)	Criteria	Category
81-100	Very high	Very Creative
61-80	Tall	Creative
41-60	Currently	Quite Creative
21-40	Low	Lack of creativity
0-20	Very Low	Not Creative

(Ekawati & Sumaryanta, 2011).

The improvement of students' creative thinking skills was analyzed using the N-gain formula, where the results will be compared with the standard criteria listed in Table 4 below:

Table 4. N-gain value criteria

N-gain value	Criteria
N-gain ≥ 0.7	Tall
0.3 ≤ N-gain < 0.7	Currently
N-gain < 0.3	Low

(Arikunto, 2009).

RESULTS AND DISCUSSION

The product produced in this study is a biochemistry practicum E-Module using the PjBL model on biotechnology materials, including bioethanol production from peatland plant biomass and virgin coconut oil production using enzymes, along with product quality tests, which were tested in the Chemistry Education Study Program, FKIP ULM Banjarmasin. The following are the results obtained in this study:

a. Analysis Stage

The analysis stage is the primary step in gathering information for product development. This information gathering takes the form of a needs analysis and a field analysis. Needs analysis helps in identifying what is needed to succeed in their studies (Giannarou, 2021). In biochemistry practicum activities in the Chemistry Education study program at FKIP ULM Banjarmasin. This stage aims to identify products suitable for chemistry education students at FKIP ULM Banjarmasin who are taking biochemistry practicum courses. This analysis was conducted by completing a Google Form prior to the research. The results of the student needs analysis indicated that additional learning media were required for Biochemistry practicums.

The ideal media, as agreed by students (66.7%), was interactive media based on the Android platform, a format they were not yet familiar with, such as Construct 2, to foster their creativity and engagement. Implementing feedback from students and assistance can ensure that the developed E-Modules are aligned with actual learning requirements. (Noorrizki et al., 2025).

The field analysis was conducted to identify the student environment and delivery strategies in biochemistry practicums. The results of the field analysis included the assistants' questions about the indicators and CPMK contained in the e-Module, the ease of use of the e-Module to avoid disrupting the practicum, and the assistants' access during the practicum.

b. Design Stage

The design phase focuses on planning and creating innovative solutions tailored to identified needs. This phase generally involves systematically structuring content and functionality. It is not just about what will be displayed, but how those elements are organized and connected to create a logical, efficient, and intuitive workflow or user experience. This structured arrangement is the foundation for easy navigation and user understanding (Arifin et al., 2023). This design phase includes selecting the software used to create the application, collecting examples of product formats and content, designing a flowchart structure, and creating a storyboard with material appropriate to the RPS for the biochemistry practicum course.

The flowchart in this study is a diagram that uses various symbols to describe the steps in product creation. The use of flowcharts in the design stage to describe complex communication systems facilitates division into modules (Yan et al., 2020). Storyboards are tools that help write short stories by emphasizing elaboration, prediction, and idea generation. The creation is developed into paragraphs, finally forming a complete explanation (Mikraj et al., 2023). Figure 1. The following shows the initial display design of the biochemistry practicum E-Module that has been developed.

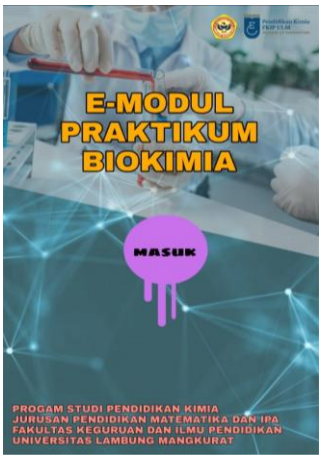

Figure 1. Initial Display Design of the Biochemistry Practical E-Module.

c. Development Stage

The development phase is the period of technical and substantial implementation that bridges the gap from a conceptual blueprint to a testable product. Its primary goal is to transform visual designs, such as storyboards or preliminary designs, into a concrete, functional product—in this context, an operational Practical Guide (Kartika & Siburian, 2023). Every frame, flow, and interaction depicted in the storyboard must be translated into tangible, structured elements of the guide. This process requires meticulous attention to detail to ensure the final product perfectly reflects the design vision and agreed-upon functional specifications.

The effectiveness of the biochemistry practicum e-module can be assessed by reviewing

the results of the validation questionnaire, which was completed by 5 validators: 4 lecturers from the Chemistry Education Study Program at FKIP ULM and 1 media expert. Table 5 below shows the results of the biochemistry practicum e-module validation questionnaire assessment by five validators:

Table 5. Validity Results of the Biochemistry Practical E-Module by the Validator

Assessment Aspects	Validator					(%)	Information
	I	II	III	IV	V		
General Aspects	16	16	16	15	14	96.25	Very Valid
Content Aspect	12	10	12	10	12	93.33	Very Valid
Language Aspects	16	16	15	13	16	95.00	Very Valid
Media Design Aspects	20	19	20	16	19	94.00	Very Valid
Average						94.69	Very Valid

Table 5 shows that the biochemistry practicum e-module achieved a validity score of 94.69%, classified as "very valid." (Widiana & Sari, 2022)To be used as a learning medium in the biochemistry practicum process. The four aspects assessed were the content aspect, which received the lowest percentage of 93.33%, and the general aspect, which received the highest percentage of 96.25%. The content aspect received a lower score because the material needed to be adjusted in depth and relevance to the very specific CPMK, especially in biochemistry practicum courses that demand conceptual precision. Expert validation often highlights the accuracy of terminology, the consistency of the material's logical flow, or the integration of the latest biochemistry concepts. The results of the general aspect assessment are in accordance with research conducted by (Puspita et al., 2021)The practicum e-module received positive responses from students who stated that it is a good e-module for practicum implementation. Validation by experts in content and media confirmed its feasibility and effectiveness, with high scores indicating their readiness for educational use. (Mustofa et al., 2023). Study (Medina M. A. et al., 2021) To confirm that the Expert feedback on the material's substance is crucial to ensure conceptual coherence and scientific accuracy. Therefore, a 1.36% decrease from the general aspect should be used as the basis to ensure that all sub-materials are presented clearly and accurately, avoiding potential misconceptions when students use them. With a content validity score of 93.33%, the researcher revised the material to optimize content aspects, including clarifying complex procedures, adding new reference sources, and adjusting scientific language. The researcher also ensured that the E-Module is tested not only as generally feasible but also sound in substance to achieve the objectives of biochemistry practical learning effectively.

d. Implementation Stage

This stage involves using the developed biochemistry practicum e-module in situations suitable for biochemistry practicum activities. This stage aims to determine the practicality of the developed biochemistry practicum e-module through individual and small-group trials, questionnaires with lab assistants and students, and observation sheets from lab assistants and students.

The readability test in the individual trial was conducted with three students, and the small-group trial was conducted with five students from class A1 of the 2019 intake of the Chemistry Education Study Program, FKIP ULM Banjarmasin. The questionnaire responses from the lab assistants and students were filled out. After conducting a limited trial on 27 A1 class students of the 2019 batch of the Chemistry Education Study Program, FKIP ULM Banjarmasin. Observation sheets were distributed to observers during the practicum activities. The student

readability test in the individual trial was 87.5%, which is in the outstanding category, and in the small group trial, 92.5%, which is also in the outstanding category (Aldilla & Usmeldi, 2024). The application of a tiered testing method (from individual to small-group) is a solid approach to validating consistency in instructional quality. The stable excellent category results in both phases prove that the developed guide has superior linguistic and pedagogical quality and is ready for broader implementation.

Readability is defined as the aspect of visual information design that affects the flow of information from the page to the reader. (Beier et al., 2021). The readability percentage indicates that this biochemistry practicum E-Module is efficient teaching material in an outstanding category, and the resulting product is worthy of future use. The opinion supports this (Pantula & Kuppusamy, 2020)that a high level of readability increases the effectiveness of writing, making content more accessible to a broader audience. This increases user engagement, comprehension, and retention, ultimately leading to better communication and dissemination of information across diverse reader demographics.

The designed biochemistry practicum E-Module is categorized as very practical based on the average score of the practicum assistant questionnaire, which is 3.3 (82.5%). This study shows that the practicum assistants responded well to the practicum activities conducted using the practicum E-Module for biochemistry that was created. The practicum assistants responded positively to the developed biochemistry practicum E-Module, as they found it suitable for use in the biochemistry practicum. This E-Module was considered very practical based on feedback from practicum assistants, with a percentage of 82.5%, indicating ease of use, suitability, and high appeal, as assessed through a practicality test questionnaire.

The designed biochemistry practicum e-module was classified as highly practical based on an average student questionnaire score of 3.22 and 83.12% pass rate. This study indicates that students responded well to the electronically prepared practical exercises in the biochemistry practicum module. The level of practicality was assessed by two different groups: assistants and students. Assessment criteria included ease of use of the media, time efficiency, interpretability, and equivalence (Rahmiati et al., 2023).

The observation sheet for the practicum assistant's ability to use the practicum E-Module was completed by four observers, containing 6 stages of the PjBL model with 16 statement items, yielding a percentage score of 93.75%. This percentage result is the result of three meetings in the practicum activity process using the developed biochemistry practicum E-Module. The practicum assistant adapted well to the biochemistry practicum E-Module and the students, making the practicum activities more dynamic and effective. The results of observations of practical skills in bioethanol and VCO experiments were classified as highly skilled. Learning activities involving seeing, doing, hearing, and moving can stimulate students' curiosity and help them develop critical thinking skills. Students then have to identify, articulate, and analyze all the material they have just learned as part of the learning process, so they can build their own knowledge and retain it for a long time. (Siregar D. & Harahap K., 2020).

e. Evaluation Stage

Feedback is a way to check how well the biochemistry lab E-Module works during the actual biochemistry lab activities. This stage assesses the performance and effectiveness of the biochemistry lab E-Module using the PjBL model to improve students' creative thinking skills. (Guo et al., 2024). The PJBL model consists of six main that is: formulating important, planning the project, creating a schedule, monitoring student activity, testing results, and evaluating experience learning, which facilitates the learning and development of practical skills (Nurinawati & Rochmiyati, 2025). This is in line with research conducted by (Rachmawati et al., 2020)To examine the results of the pre-test and post-test, which were then analyzed using

N-gain, this method helps determine the effectiveness of the biochemistry practicum E-Module product.

Stages of testing the effectiveness of the practical E-Module biochemistry-based PjBL show that this model significantly increases creative students' skills, as evidenced by an N-gain score of 0.72 (category tall). The use of the PjBL model to improve creativity (Ermiyati et al., 2024), especially in the indicators of Originality, Fluency, and Flexibility, can be explained through the following specific stages:

Stage: formulate an important question and monitor activities. Stages: This is a trigger for beginning creativity. When students are faced with open, complex questions in a practicum that require a practical solution, they are forced to develop Fluency and Flexibility to formulate multiple approaches to solve the problem. (Ariana & Jordy, 2022). Stage plan projects and create a schedule: in this stage, the PjBL E-Module pushes students to make an independent practicum design (determining the title, objectives, tools, and procedures). This requirement directly increases the Originality indicator because students must develop unique, novel ideas and procedures rather than simply following standard instructions. This stage's contribution to Originality was most strongly demonstrated in this study. Stage test results and evaluate experience learning: stages. Testing and evaluation are crucial for honing critical thinking and elaboration skills. Students are encouraged to analyze the strengths and weaknesses of their designs and then seek ways to improve them. This reflective process has proven crucial in developing these skills. Think creatively in a sustainable way. (Azis, 2024).

The success of the PjBL E-Module in improving creative thinking skills is supported by the open-ended task elements contained therein (formulating questions and planning projects), which effectively stimulate three leading indicators of creativity. Evidence of this increase, both through the average percentage (Pretest and Posttest) presented in Figure 2, and the level (N-Gain) of each indicator presented in Figure 3, below:

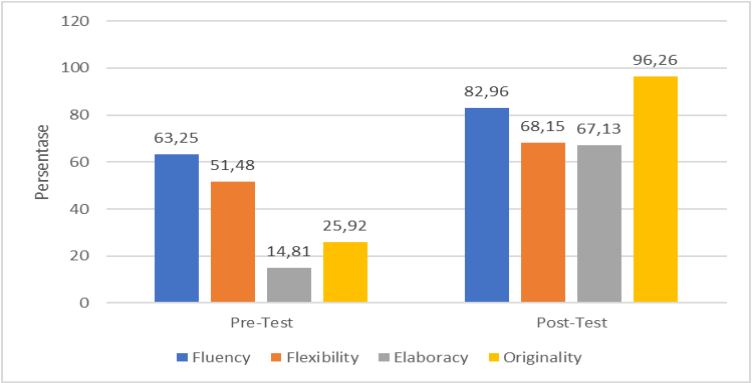

Figure 2. Average Level of Creative Thinking Skills for Each Indicator (Pretest and Posttest)

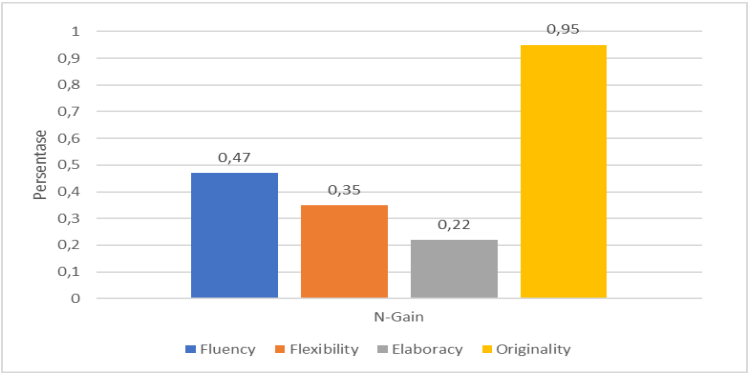

Figure 3. Average Level of Creative Thinking Skills for Each Indicator (N-Gain)

The originality indicator has a high n-gain achievement of 0.95. This is because, in the E-Module for biochemistry practicum, using the PjBL model, a clear element design stimulates indicator originality in students, through a task-based project in the form of independent practical design work. This matter can be seen in the E-Module, which directs students to create a practical design, including determining the title, objectives of the practicum, tools and materials, and practicum procedures. The students' obligation to compile all elements of the practicum design from beginning to end trains them to produce unique, original ideas, which are the essence of originality. (Ariana & Jordy, 2022). The achievement of a very high N-gain (0.95) demonstrates that the project assignment is highly effective in improving students' ability to create and innovate originally. The elaboration indicator had a low n-gain of 0.22, despite an increase in the pre-test-to-post-test percentage. This was because students still provided correct answers, but they were unclear and insufficiently detailed.

CONCLUSION AND RECOMMENDATIONS

Based on the data analysis and discussion, research on the development of practical E-Modules in biochemistry using the PjBL model yields three main conclusions. Validity of the practical E-Module: The developed biochemistry was deemed (very) valid by expert validators. Four rated aspects, general, content, language, and media design as a whole, fulfill standard criteria eligibility to be used as a learning medium in biochemistry practical activities. The E-Module is highly practical. Used in the field. These results are supported by findings from individual and small group trials that showed an outstanding category (readability), as well as positive responses from students and lab assistants who consistently classified it as very practical. Effectiveness of Practical E-Modules: biochemistry-based PjBL has met the criteria for high effectiveness in improving students' creative thinking skills. This improvement was demonstrated quantitatively by high N-gain scores, with students showing consistent gains in each indicator of creative thinking skills from pre-test to post-test. Resulting creative productivity (Originality and Elaboration). Through the task project open (design practical work independently), which is embedded in the E-Module. Research confirms that the PjBL E-Module not only serves as a medium for conveying material but also becomes the leading platform that inherently facilitates the PjBL stages that demand ideas and solutions. New, which has not been fully shown by the study of the PjBL E-Module in the context of science, other. It is expected that the development of practical E-Modules in biochemistry as a learning medium will enable further research on a larger scale, using more innovative learning designs and models tailored to current needs. Researchers are also expected to include more chemistry learning materials for teaching and supplementary media in chemistry learning.

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