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Natural product chemistry laboratory project to improve creative thinking skills

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Abstract This research was conducted to examine the application of a natural product chemistry laboratory project to enhance students' creative thinking skills. A quasi-experimental method was employed, with participants comprising 26 students in the experimental class and 26 students in the control class, all of whom were chemistry education students in the 7th semester of the 2024/2025 academic year at a state university in West Nusa Tenggara, Indonesia. In the experimental class, a natural product chemistry laboratory project was implemented, whereas in the control class, a verification laboratory approach was used. The results indicated a significant difference in creative thinking skills (fluency, flexibility, originality, and elaboration) between the experimental and control classes. Additionally, the average n-gain test results revealed a moderate increase in the experimental class (34.12), compared to a low increase in the control class (27.27). These findings suggest that the natural product chemistry laboratory project enhances students' creative thinking skills more effectively than the conventional laboratory approach.

Keywords: project, conventional, laboratory, creative thinking skills

1. Introduction

In an increasingly complex era of globalization, education must innovate to produce graduates with theoretical knowledge, practical skills, and high creativity (Rahmulyana et al., 2024; Pamungkas et al., 2024). Creative thinking skills are among the important competencies that students must have. This ability helps solve scientific problems and is relevant in various aspects of professional and personal life (Zakiah et al., 2020). Innovation is needed in teaching methods to improve creative thinking skills, including in the natural product chemistry laboratory (Tiak et al., 2019). One promising approach is the project-based laboratory model, which is believed to have a more significant impact than conventional practicum models do (Andayani et al., 2018; Haryudo et al., 2020; Pauzi et al., 2024).

Traditionally, the conventional laboratory has been widely used, where students focus on following established standard procedures to confirm the concepts they have learned (Hakim, et al., 2021; White & Forgasz, 2016). Even though it is effective in helping students understand basic concepts and laboratory skills, the limitations of this laboratory often do not provide enough space for developing students' creative thinking skills (Dasna, 2018; Arsyad, 2023). Students follow instructions without much opportunity to think critically or creatively in overcoming unexpected problems (Supatmi, 2022).

Alternatively, a natural product chemistry laboratory project has been proposed to improve creative thinking skills more effectively (Cahyaningsih & Harun, 2023). This model emphasizes project-based learning, in which students are challenged to design, implement, and analyze their research projects. Through this approach, students learn through experiments and critical and creative thinking processes to overcome real problems faced during a project (Kumalasari et al., 2024; Zulyusri et al., 2023).

Students integrate theoretical knowledge with practical applications through real projects based on local medicinal plants. Thus, this laboratory project makes learning more exciting and meaningful because it directly relates to the surrounding environment and local potential. This process encourages students to think critically and creatively when dealing with problems that arise during experiments (Ardiansyah et al., 2023). This approach enriches students' understanding of natural product chemistry and creative thinking skills and makes a real contribution to the local community.

Project-based learning (PjBL) has been recognized as effective in improving creative thinking skills. Rosita et al. (2024) reported that ethnoscience-based PjBL has a positive effect on increasing collaboration, critical reasoning and student creativity. Furthermore, Pauzi et al. (2024) reported that implementing PjBL improved students' creative thinking abilities and fostered their interest in learning the skills to communicate, collaborate, solve problems, and collect and analyze the information obtained. According to Chen et al. (2022), through discovery and problem solving, PjBL improves students' creative thinking skills, especially fluency and flexibility. In addition, research by Novitasari (2023) also shows that project-

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based learning can increase student involvement and provide a more meaningful learning experience. PjBL on project practicum has an impact on students' creative thinking and collaboration skills. Laboratory activities encourage students to be more active and interact with each other (Khoiri et al., 2023; Ekaputra, 2024; Purba, 2024).

Thus, this research aims to examine the application of the natural product chemistry laboratory project to improve students' creative thinking skills. This research provides new insight into the effectiveness of the natural product chemistry project.

2. Methodology

This study uses quasiexperimental methods (Cresswell, 2007). This research was carried out via quasiexperimental methods. The participants consisted of 26 students in the experimental class and 26 students in the control class for chemistry education during the 7th semester of the 2024–2025 academic year from a state university in West Nusa Tenggara, Indonesia.The identity of the participants in the data collection is confidential. The data disseminated is the result of data collection on creative thinking skills as a result of the implementation of the PjBL model in the Natural Product Chemistry Laboratory Project (NPCLP).

This research developed a laboratory project called the Natural Product Chemistry Laboratory Project (NPCLP). NPCLP begins with a problem to be solved by the students. The problem is "how do you isolate one of the secondary metabolites of a rhizome of *Curcuma xanthorrhiza,* a rhizome of *Kaemferia pandurata*, a rind of *Garcinia mangostana,* a fruit of *Piper nigrum*?" These plants are used in traditional Indonesian medicine. The experimental class used the NPCLP, and the control class used the verification laboratory. The differences in the activities of the NPCLP and control classes used in the verification laboratory can be seen in Table 1.

Students' creative thinking skills were measured via two instruments, namely, the creative thinking skills test instrument and the observation sheet assessment instrument. The two instruments developed by researchers are based on aspects of creative thinking skills according to Torrance (1977), namely, *fluency* (thinking smoothly), *flexibility* (thinking flexibly), *originality* (original thinking), and *elaboration* (thinking elaboration). An observation sheet instrument was used at each stage of the laboratory learning process. The assessment indicators can be seen in Table 2.

Table 1 Differences in the Activities of the Experimental Group and Control Group.

Natural Product Chemistry Laboratory Project		Verification Laboratory	
Introduction	1. Explanation of lecture contracts: explanation of laboratory scheduling 2. Introduction to medicinal plants 3. Prerequisite tests (diagnostic tests to gain a basic understanding of chromatography and spectroscopy techniques) 4. *Pretest* (diagnostic test before the learning process)	Introduction	1. Explanation of lecture contracts: explanation of laboratory scheduling 2. Introduction to medicinal plants 3. Prerequisite tests (diagnostic tests to gain a basic understanding of chromatography and spectroscopy techniques.) 4. *Pretest* (diagnostic test before the learning process)
Pre-Laboratory	1. Formation of groups based on prerequisite test results and *Pretest* (3-4 students per group) & determine the roles of team members in the group 2. The lecturer explains several concepts that have the highest percentage of errors based on the prerequisite test results 3. Lecturers and laboratory assistants guide and provide information to students about several tools that will be used to isolate medicinal plants 4. Students can ask questions and provide suggestions	Pre-Laboratory	1. Formation of groups based on prerequisite test results and *Pretest* (3-4 students per group) & determine the roles of team members in the group 2. The lecturer explains several concepts that have the highest percentage of errors based on the prerequisite test results 3. Lecturers and laboratory assistants guide and provide information to students about several tools that will be used to isolate medicinal plants 4. Students can ask questions and provide suggestions
Problem orientation	1. Students were asked to look for information about medicinal plants that grow around them 2. Students were asked to presented the medicinal plants 3. Students were asked, "What is the secondary metabolite compounds and how to	Problem orientation	1. Students are given medicinal plant to isolate 2. The lecturer explained and distributed a laboratory module to each group, which contains procedures for isolating secondary metabolite compounds

	isolate the secondary metabolite from one of the medicinal plants that has been presented?" 4. Each group determines which medicinal plant will be isolated 5. The lecturer explained the general procedures for isolating secondary metabolite compounds		
Preparation of laboratory proposals	1. Students carry out literature reviews from various relevant sources 2. Students make proposals containing three procedures for isolating secondary metabolite compounds from 3 specified medicinal plants. 3. The lecturer was a facilitator and provides time to receive questions and guide students.	Preparation of laboratory proposals	1. Students used the module guide that has been given as a literature review in the preparation of the laboratory proposal 2. The lecturer acted as a facilitator and provides time to receive questions and provide guidance to students
Laboratory proposal presentation	1. Students communicated their proposals to other groups through presentations. 2. Students from other groups obtain information and respond to submitted proposals. 3. Students determined one medicinal plant to isolate based on the most significant opportunity to successfully isolate secondary metabolite compounds from the three medicinal plants 4. The lecturer acted as a facilitator for various problems that arise during class discussions.	Laboratory proposal presentation	Students do not present practical proposals
Application of practical activities	1. Students implemented their proposals and collected practical data from sample preparation, extraction, fractionation, & purification of compound secondary metabolites. 2. The lecturer acted as a facilitator and guided the investigation.	Application of practical activities	1. Students implemented laboratory activities according to the modules that have been given. 2. The lecturer acted as a facilitator and guided the investigation.
Reporting and presentation of laboratory results	1. Students make reports on the results of investigations during the laboratory implementation. 2. Each practicum group communicates their laboratory results to other groups through presentations. 3. Students from other groups obtain information and respond to laboratory results reports. 4. The lecturer acted as a facilitator for various problems that arise during class discussions.	Reporting and presentation of laboratory results	1. Students make reports on the results of investigations during the laboratory implementation. 2. Each group communicates their laboratory results to other groups through presentations. 3. Students from other groups obtain information and respond to laboratory results reports. 4. The lecturer acted as a facilitator for various problems that arise during class discussions.
Evaluation of practical activities and analysis of complex concepts	1. Students evaluated the practical activities that have been carried out. 2. Students make conclusion from the information they have obtained during laboratory activities 3. *Posttest*	Evaluation of practical activities and analysis of complex concepts	1. Students evaluate the practical activities that have been carried out. 2. Students make conclusion from the information they have obtained during laboratory activities 3. *Posttest*

3. Results

The focus of this research is to examine the application of the natural product chemistry laboratory project to improve students' creative thinking skills. Validation of data collection instruments includes construct validation of the learning development model (Table 3) and empirical validation of creative thinking skills data collection instruments (Table 4). The results of the statistical tests on students' creative thinking skills in the experimental and control classes are presented in Table 5.

Table 2 Assessment indicators for the observation sheet for Practicum implementation.

Practical activity steps	Indicator
Introduction	Convey the purpose and importance of laboratory activities (fluency). Connecting laboratory activities with the chemical concept of natural product and medicinal plant (flexibility).
Prepracticum	Understand the basics of relevant theories (originality) Identify tools and materials to be used (fluency)
Problem orientation based on local medicinal plants as practical samples	Explain the characteristics of the medicinal plant (fluency) Connecting the benefits of plants with chemical applications of natural ingredients (flexibility)
Preparation of practicum proposals	Produced many ideas for laboratory designs (Fluency) Demonstrated ability to think from multiple perspectives (Flexibility) Generate unique and innovative ideas (Originality) Develop proposals in detail and in-depth (Elaboration)
Practical proposal presentation	Convey ideas clearly and systematically (originality) Receive and respond to input well (elaboration)
Application of practical activities	Implement methods with flexibility and adaptation (flexibility) Creating innovative solutions during laboratory implementation (originality) Explain each laboratory step in detail (elaboration)
Reporting and presentation of practicum results	Produce detailed and in-depth reports (originality) Present laboratory results clearly and interestingly elaboration)
Evaluation of practical activities and analysis of complex concepts	Assessing the effectiveness of the method and the results achieved (originality) Connecting laboratory results with natural product chemistry concepts (elaboration)

Table 3 Expert validation of learning model development.

Component	Aiken's Value	Criteria
Content	0.78	Valid
Construct	0.80	Valid
Language	0.85	Valid

Table 4 Empirical validity and reliability of creative thinking skills test instruments.

Component	Instrumen test code	Average correlation value	Criteria
Fluency	i1, i2, i3, i4,i5	0.65	Valid
Flexibility	I6, i7, i8, i9,i10	0.71	Valid
Originality	I11, i12, i13, i14,i15	0.74	Valid
Elaboration	i16, i17, i18, i19,i20	0.69	Valid
Cronbach's Alpha		0.519	Medium

Table 5 Recapitulation of the statistical tests.

Component	Pretest		Posttest	
	Experiment	Control	Experiment	Control
n	26	26	26	26
Rate-rate	57,76	12,42	17,5	15,07
Standard Deviation	3,12	3,15	2,07	2,65
Maximum Score	68	19	20	19
Shoes Minimum	53	9	13	11
Normality Test				
Significance value (p)	9,43	0,14	0,17	0,15
Information	Normally distributed	Normally distributed	Normally distributed	Normally distributed
Homogeneity Test				
Significance level (p)	1,1		1,03	
Information	Homogeneous		Homogeneous	
Hypothesis Testing				
	Uji t		Uji t	
Significance level (p)	43,56		28,54	
Description (H_0 : $m_1 = \mu_2$)	H_0 Rejected		H_0 Rejected	

Compared with the control class, the experimental class presented a greater average score for creative thinking skills in the posttest. The t test results revealed a p value < 0.05 for all aspects of creative thinking skills, which means that there was a significant difference between the experimental class and the control class. Compared with the control class, the experimental class presented a significant increase in creative thinking skills. The average values of the elaboration aspects are presented in Table 6.

Table 6 Comparison of the average results of students' creative thinking skills on the Practicum implementation observation sheet.

Indicator	Experimental Class		Control Class	
	Rate-rate	Percentage	Rate-rate	Percentage
Fluency	16,69	21%	14,62	18%
Flexibility	17	21%	14,62	18%
Originality	25,92	32%	21,92	27%
Elaboration	21,5	27%	18,27	23%

4. Discussion

Several factors may explain this significant increase. First, the project-based laboratory provides a more in-depth and contextual learning experience. Students were directly involved in experimental processes that were challenging and relevant to real life. Through this project, students were invited to think critically and creatively in designing experiments, analyzing data, and developing innovative solutions (Yanti & Rahmad, 2023). This can be seen in the results of the average value of the elaboration aspect, which increased more than the other aspects did (Table 4). This was also in accordance with the results of research conducted by Sudirman et al. (2024) on collaborative project-based learning that utilized local potential, which revealed significant differences, namely, the effectiveness of learning approaches that emphasize active involvement, exploration and contextual relevance. Second, this project encouraged collaboration and communication between students. In completing projects, students work in teams, share ideas, and solve problems. This process not only improves collaborative skills but also encourages the emergence of diverse creative ideas (Mona & Rachmawati, 2023). Third, students feel more motivated and enthusiastic about learning because projects related to their lives can make real contributions to society (Baran, et al., 2021). This motivation was an important factor in encouraging active involvement and the development of creative thinking skills.

A comparison of creative thinking skills in the Natural Product Chemistry Laboratory Project class in all aspects revealed higher average scores than did Conventional Laboratory classes. Apart from that, the average comparison of aspects of creative thinking skills due to observations of traditional laboratory implementation was lower than that of project-based laboratories (Table 4). Analysis of the average N-gain test results revealed an increase, which was classified as moderate in the experimental class. In contrast, the control class increased and was classified as low. Compared with the control class, there was a greater increase in creative thinking skills for each indicator (*fluency, flexibility, originality,* and *elaboration*), which indicated that the Natural Product Chemistry Laboratory Project was more effective in improving students' creative thinking skills. PjBL in natural material chemistry practicums makes students play an active role in elaborating with natural materials. activities to find active compounds from various types of medicinal plants provide a flexible experience in working in the laboratory. This motivation can only be obtained through laboratory activities with PjBL procedures that have been determined when preparing activities. PjBL emphasizes students to be more independent in designing experimental designs with various sources of research journals. activity process can influence the emergence of students' creative thinking abilities.

The average score for all aspects of creative thinking skills increased after learning was carried out. In terms of aspects*, flexibility increased the most because students are required to think adaptively and consider various solutions when* designing project-based natural product chemistry practicum activities. In the project-based practicum process, students are encouraged to consider various methods and approaches to solving problems so that they tend to think flexibly in finding effective and efficient solutions (De & Mahtari, 2022). In addition, projects related to natural product chemistry and local Sasambo plants provide a rich and varied context for students to apply the concepts they have learned. This encourages students to think flexibly in solving complex and varied problems (Putri, et al., 2021).

The results of the conventional laboratory class showed an average score for each aspect of creative thinking skills before and after learning. However, the increase in score was still relatively low. This can be seen in the practicum activities carried out by students who follow the practicum instructions, thus limiting the space for exploring students' creative ideas (Putri et al., 2021). This is also confirmed by research by Ningsih et al. (2020) on the use of project-based learning to improve creative thinking skills.

5. Conclusions

The results showed that, compared with conventional laboratories, the Natural Product Chemistry Laboratory Project, which uses medicinal plants, can be an effective alternative learning method for improving students' creative thinking skills. A greater increase in each indicator of creative thinking skills (*fluency, flexibility, originality,* and *elaboration*) indicates that the Natural Product Chemistry Laboratory Project was more effective than the conventional laboratory in improving students' creative thinking skills.

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Ethical considerations

Not applicable.

Conflict of interest

The authors declare that they have no conflicts of interest.

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