Development of PjBL STEM Model to Improve Student's Creative Thinking Ability

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Abstract. After completing their university education, students should possess the ability to think creatively, since it is one of the most significant aims at all educational levels. It is necessary for lecturers to be able to create and plan lessons that will enable students to actively participate and hone their creative thinking abilities. This project aims to create organic compounds and reactions-focused general chemistry teaching materials (books) that can enhance students' capacity for creative thought by utilizing a reliable PjBL STEM paradigm. The ADDIE development model is the one that is being utilized. Teaching materials (books) based on the PjBL STEM model were developed through research and development. They are viable (valid) for use in teaching compounds and organic reactions, and they have been shown to significantly improve students' capacity for creative thought ($p = 0.000 < 0.05$).

Keywords: PjBl, STEM, Creative Thinking Ability.

1 Introduction

Formal education has to change, according to an increasing number of people, because a global movement advocating for 21st-century learning paradigms emerged. The modifications in question are to pedagogy, specifically the transition from simple to comprehensive action and the replacement of traditional teaching methods with technology-based instruction. They do not entail modifications to the curriculum material [1]. Determine the skills and knowledge that students need to acquire in order to meet the challenges of the modern world. These include the capacity for creative thought, effective communication, innovation, and problem-solving via cooperation and negotiation [2].

At all educational levels, developing creative thinking abilities is one of the most crucial objectives. This ability pertains to the capacity to recognize, evaluate, and resolve issues in a creative and rational manner in order to arrive at the best conclusions and choices [3]. Students who possess these qualities or skills are highly valued since they enable them to act sensibly and select the finest options available to them. Depending on the activities that are

ICIESC 2023, October 24, Medan, Indonesia

DOI 10.4108/eai.24-10-2023.2342336

frequently performed to cultivate them, each person has distinct creative thinking abilities and capabilities [4].

Educators, including lecturers, must also be able to create learning experiences that are focused on actively involving students and that encourage them to use their creativity to solve challenges [4]. Students need to find ways to develop their creative thinking skills immediately because they are essential life skills that they will need after they graduate from college. A student's capacity for creative thought is crucial since it serves as a foundation for problem-solving at all times. This includes doing scientific tasks including posing queries, forming conclusions, selecting the best course of action, and formulating judgment calls in chemistry experiments [5].

The instructor or lecturer serves as a facilitator in a student-centered learning environment according to the principles of 21st century learning. The focus of 21st century education is on students' problem-solving skills, their ability to gather information from several sources, their analytical and creative thinking, and their ability to work together to solve problems [6]. Project-based learning is an alternate approach that can be used to enhance students' capacity for creative thought, particularly when studying chemistry (PjBL). PjBL incorporates the 4C: Creativity, Communication, Cooperation, and Creativity. As such, it is a perfect model to support 21st century educational aims [7].

PjBL is now a learning model that complements the 2013 curriculum since it has the ability to give students a more engaging and meaningful educational experience [8]. Through collaborative decision-making, PjBL students design their own learning process, carry out research, and produce creative products that make use of their knowledge. This can be accomplished by utilizing technology to provide a variety of knowledge and skills, then refining the students' problem-solving and communication abilities [9]. Additionally, numerous research demonstrate the effectiveness of PjBL application in the learning process [10], potential to boost engagement and academic success in students [11], enhance your capacity for creative thought [12], improve communication skills [13], improve creative thinking abilities [14] [15], improving collaboration skills and learning outcomes [16], improving literacy skills [17], and being able to increase students' HOTS [18] [19] [7].

One of the abilities that every student has to possess in order to successfully navigate obstacles, issues, life, and careers in the twenty-first century is creative thinking. The swift advancement of science and technology necessitates that instructors provide their pupils with creative thinking skills and multidisciplinary competence. The STEM fields science, technology, engineering, and mathematics are the knowledgeable domains required to handle these diverse issues. STEM encompasses analytical, collaborative, and creative thinking processes where students apply concepts and procedures to real-world scientific situations and develop skills and competences for college, careers, and everyday life [20].

In order to assist develop 21st century abilities, the integration of science, technology, engineering, and mathematics education is known as the STEM learning strategy. The integration of STEM learning has a significant impact on academic performance. If STEM is connected to the environment, it can grow and provide learning that reflects the real world that children encounter on a daily basis. This indicates that by using the STEM approach, students learn how to comprehend scientific ideas and how they relate to real-world situations rather than just memorizing facts [21]. Additionally, a number of studies demonstrate that the STEM method might enhance students capacity for creative thought [22] [23] [24] [25], improving creative thinking skills [26], and able to improve student learning outcomes [27] [28].

2 Method

The ultimate objective of this research is to provide general chemistry teaching resources that are appropriate for enhancing students' critical thinking abilities and are based on the PjBL STEM model. This study is an example of research and development (R&D), which is a process used to create and validate educational goods and evaluate their efficacy. Unlike theory testing, R&D generates products through its research.
The substance created consists of organic processes and chemicals. Forty students served as the study subjects, and the development approach that was employed was the ADDIE development process, which included the following: (1) Analysis, which involved gathering data on student needs by analysis and reading up on relevant literature regarding the product under development; Design is the process of determining goals and developing a plan for instructional materials based on the PjBL STEM model of organic molecules and reactions that will be created; (3) Development: This phase entails transforming the design into a workable product; (4) Implementation: this involves utilizing the product general chemistry teaching materials to teach students about organic compounds and reactions using the PjBL STEM model; and (5) Evaluation: this involves assessing students' innovative problem-solving skills as they learn about organic compounds and reactions.
In order to acquire knowledge for future research projects and product trials, researchers use a variety of data collection techniques and methods. These include: (1) conducting interviews as a preliminary study material to identify potential research topics; (2) using validation sheets to gather information about expert validation results for teaching materials based on the PjBL STEM model on the material on organic compounds and reactions being developed; and (3) using expert validation with validators to identify potential problems to be researched and used in product trials; and (3) Test instrument: designed to gather information about students' capacity for original thought when researching organic chemicals and reactions. The test is designed as a description/essay test and is organized based on the candidate's competency achievements in understanding organic substances and reactions.
The feasibility (validity) and efficacy of the learning that was being designed were ascertained by a phased analysis of the research data. Based on the findings of expert validation and taking into account feedback, comments, and recommendations from expert validators, the viability (validity) of instructional materials developed using the PjBL STEM paradigm is examined. Assessments of students' capacity for creative thought are used to determine how successful PjBL STEM-based teaching materials are. With the aid of the SPSS software, the efficacy test was examined by enhancing students' capacity for original thought through the use of the t-test or paired sample t-test technique.

3 Results and Discussion

In order to facilitate learning for both lecturers and students and to enhance students' capacity for creative thought when studying organic compounds and reactions, this research and development project produced general chemistry teaching materials based on the PjBL STEM model. Skilled specialists in specific domains, such as media and material experts, evaluate the appropriateness or validity of instructional materials. After being deemed valid (feasible) by expert validators through assessments, general chemistry teaching materials based on the PjBL STEM model for understanding organic compounds and reactions will be put into use.

Students will then be able to evaluate the efficacy of the materials based on how well their creative thinking skills are working.

3.1 Feasibility (validity) of the Product

Expert validators reviewed and assessed the viability (validity) of General Chemistry teaching materials based on the PjBL STEM model for learning organic molecules and reactions based on the material's and the media's suitability.

Table 1. Results of Validation of Teaching Materials on Material Aspects

Assessment Aspect	Validator (Mean score)			Total Mean	Criteria
	I	II	III		
Content material	4.63	4.38	4.88	4.63	Valid
Presentation of material	4.38	4.50	4.38	4.42	Valid
Language	4.33	4.67	4.33	4.44	Valid
Using of learning models	5.00	5.00	4.80	4.93	Valid
Evaluation and assesment	4.50	4.67	4.50	4.56	Valid
Total average				4.60	Valid

Table 1, reflects the evaluation findings from the material expert validators, and it is determined that the material has met the valid criteria when an average total score of 4.60 is reached. Therefore, it can be said that the PjBL STEM-based general chemistry teaching materials are legitimate based on their material aspect and may be used to teach students about organic molecules and reactions.

Table 2. Results of Validation of Teaching Materials in Media/Design Aspects

Assessment Aspect	Validator (Mean score)			Total Mean	Criteria
	I	II	III		
Graphics	4.67	4.50	4.67	4.61	Valid
Language	4.74	4.88	4.63	4.75	Valid
Total average				4.68	Valid

Table 2, presents the evaluation findings from the media (design) professional validators, who determined that the project matched the relevant criteria with an average overall score of 4.68. Therefore, it can be said that teaching materials for general chemistry based on the PjBL STEM paradigm are legitimate in terms of media (design) and appropriate for use in the process of teaching students about organic compounds and reactions.

3.2 Achievement of Students' Creative Thinking Abilities

Tests of students' capacity for creative thought were administered both before (pretest) and after (posttest) of learning activities including the use of General Chemistry instructional materials derived from the resulting PjBL STEM model. 40 students in one class were used to test the final teaching materials, which were implemented in three stages, including: (a) the first step, which is the pretest before learning actions are given to students; (b) the second step, which is the action or process learning where students use the General Chemistry teaching materials created using the PjBL STEM model to learn about organic compounds and reactions; and (c) the third step, which is the final test (posttest) following the completion of all learning material.

Table 3. Achievement of Students' Creative Thinking Abilities

	Pre-test	**Post-test**
N (Number of student)	40	40
Minimum	35	75
Maximum	55	98
Mean	46.18	88.90
Std. Deviation	4.402	4,960
K-S test	0.136	0.128
Sig.	0.061	0.097

Table 3, represents the students' creative thinking pretest scores prior to any action being taken. With a normal distribution and a Kolmogorov-Smirnov test (K-S test) score of 0.136 (p = 0.061), the pretest average was 46.18 ± 4.402. Following the implementation of PjBL STEM-based General Chemistry teaching materials, students' creative thinking capacity was assessed at 88.90 ± 4.960 on average in the post-test. The data was distributed normally, with a K-S test of 0.128 (p = 0.097) and a normal distribution.

3.3 Product Effectiveness

Implementation data based on the success of enhancing students' creative thinking abilities determines the effectiveness of the product in the form of General Chemistry teaching materials based on the PjBL STEM model in teaching organic molecules and reactions. The SPSS software was used to examine the efficacy of enhancing students creative thinking skills using a paired sample t-test method.

Table 4. Product Effectiveness Test Results

	Paired Differences		t	sig
	Mean	*Std. Deviation*		
Posttest – pretest	42,725	8,317	32,488	0,000

Table 4, reveals the findings of the analysis of improving students' creative thinking skills, with a difference in average scores (posttest-pretest) of 42.725 ± 8.317 and a t-count value of 32.488 with a probability (sig.) of 0.000 < 0, 05 obtained from hypothesis testing. In light of this, it can be said that using general chemistry teaching materials based on the PjBL STEM model has greatly enhanced students' capacity for original thought when studying organic molecules and reactions.

3.4 Discussion

General Chemistry teaching resources built on the PjBL STEM model for understanding organic substances and reactions are the educational goods created in this research and development project. Utilizing the ADDIE development model as a guide, the instructional material was created. The General Chemistry teaching materials prepared using the PjBL STEM model have been deemed legitimate and appropriate for use in the educational process by the expert validator. According to the National Education Standards Agency (BNSP), the appropriateness of material content, presentation of material, language, use of learning models, evaluation and assessment, as well as graphics with modifications in accordance with teaching materials at tertiary institutions (universities), are all examples of how the validity of teaching materials is fulfilled qualitatively based on the assessment of material expert validators and media (design) expert validators.

Throughout the implementation phase, it has also been shown that using PjBL STEM-based General Chemistry teaching resources to help students learn about organic molecules and reactions can enhance their capacity for creative thought. The statistical measure of effectiveness is the rise in students' capacity for creative thought as measured by their performance on tests of creative thinking ability based on data from pre- and post-tests taken before and after the learning event. Positive feedback was also received from students regarding the General Chemistry teaching materials developed using the PjBL STEM approach.

The study's conclusions are consistent with earlier research demonstrating that PjBL can enhance students capacity for creative thinking [12], [14], [15], and the STEM approach can improve students' creative thinking abilities [22], [23], [24], [25], [26].

The results of this research and development also have implications for educators, as they show that innovative learning can be designed and developed, with the creation of teaching materials based on the PjBL STEM model being one way to improve the achievement of learning outcomes, particularly students' creative thinking abilities. With the use of instructional materials based on the PjBL STEM model, students' comprehension, mastery, and capacity for creative thought can all be enhanced.

4 Conclusion

In terms of aspects such as appropriateness of material content, presentation of material, language, use of learning models, evaluation and assessment, as well as appropriateness of graphics according to BSNP with modifications in accordance with teaching materials at university level, this research and development produced educational products in the form of General Chemistry teaching materials (books) based on the PjBL STEM model on Organic Compounds and Reactions. These were developed using the ADDIE development model and have been declared valid (feasible) to be applied to the study of organic compounds and reactions. The integration of PjBL STEM-based teaching materials for General Chemistry has demonstrated efficacy in enhancing students' creative thinking skills when it comes to learning organic compounds and reactions. Test results have demonstrated an average increase in students' creative thinking ability scores (post-pretest) of 42.725 ± 8.317. statistical hypothesis with p (0.000) < 0.05 as the probability value. The goal of this research and development is to provide users, development researchers, and other lecturers with ideas for future research and development linked to teaching materials for additional courses that use the PjBL STEM model.

Acknowledgments. We express our gratitude to all of the supervisors and participants in this study, as well as to LPPM Universitas Negeri Medan for providing research assistance.

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