The role of engagement, content, and understanding of numeracy literacy in physics creativity projects

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Abstract
Pre-service physics teachers engagement and content material influence the strategies for implementing creative learning. Behavioural, emotional, cognitive, and reciprocal aspects are less visible during classroom learning. Content material can present several interesting topics that are more engaging if pre-service physics teachers s are directly involved through demonstrations, experiments, and learning in their surroundings. The approach aims to build interest and active engagement to complete project activities. The study seeks to determine whether project-based learning with active pre-service physics teachers engagement, content delivery, and numeracy literacy understanding can be enhanced through creative projects. The research uses a quasi-experimental design with control and experimental groups using pretest and post-test. A total of 39 pre-service physics teachers s were enrolled in this study, divided into two groups: the experimental group consisted of 21 pre-service physics teachers s who received instruction using the STEM-based creativity project method, and the control group consisted of 18 pre-service physics teachers s who received instruction using the inquiry and assignment method. Both classes were analysed based on pre-service physics teachers engagement, content material presentation, and numeracy literacy understanding. The study measured pre-service physics teachers performance before and after the intervention using tests. Pretest findings showed a p-value greater than 0.05 between the control and experimental groups, indicating no statistically significant difference between the two groups. A post-test showed a p-value of <0.001 between the groups, indicating that the experimental group significantly outperformed the control group. The findings of this study suggest that pre-service physics teachers engagement, content material packaging, and numeracy literacy understanding influence creative projects. This study supports the development of STEM-based creativity project learning and active pre-service physics teachers participation.

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1. Introduction

Numeracy literacy, which includes the ability to think quantitatively and use numbers and data in the context of everyday life, is one of the basic skills needed in learning physics (Chan & Rao, 2024; Dorris et al., 2024). In an increasingly complex and technology-based world, numeracy literacy becomes more relevant because it helps pre-service physics teachers s understand physics concepts more deeply and solve practical and theoretical problems (Zummo et al., 2023).

However, various studies show that numeracy literacy among pre-service physics teachers s in Indonesia is still at an inadequate level. The PISA (Program for International Pre-service physics teachers Assessment) survey conducted by the OECD indicates that Indonesian pre-service physics teachers s' numeracy literacy abilities are still lagging compared to other countries. This is a serious concern for educators, especially in numeracy-based subjects such as physics (Mertanen & Brunila, 2024; Rappleye et al., 2024). One way to overcome this problem is to integrate creativity-based projects that involve numeracy skills into physics learning so that pre-service physics teachers s can understand physics concepts through a more practical and contextual approach (Chan & Rao, 2024; Wahlström & Nordin, 2024).

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The problems of this research include the low numeracy literacy of pre-service physics teachers s in physics learning, the lack of active engagement of pre-service physics teachers s in the learning process, which causes minimal understanding of concepts, and the limited quality of relevant and contextual learning content. Traditional learning approaches often cannot link theory with relevant practical applications, so pre-service physics teachers s have difficulty understanding how physics concepts and numeracy literacy are applied in everyday life. In addition, there are few studies on how integrating pre-service physics teachers engagement, creative content, and numeracy can improve physics learning, primarily through challenging creativity-based projects (Bonifacci et al., 2021; Hoareau & Tazouti, 2024; Iswara et al., n.d.; Mertanen & Brunila, 2024).

The problems of this research include the low numeracy literacy of pre-service physics teachers s in physics learning, the lack of active engagement of pre-service physics teachers s in the learning process, which causes minimal understanding of concepts, and the limited quality of relevant and contextual learning content. Traditional learning approaches often cannot link theory with relevant practical applications, so pre-service physics teachers s have difficulty understanding how physics concepts and numeracy literacy are applied in everyday life. In addition, there are few studies on how integrating pre-service physics teachers engagement, creative content, and numeracy literacy can improve physics learning, primarily through challenging creativity-based projects (Hoareau & Tazouti, 2024; Iswara et al., n.d.; Kirksey et al., 2023).

The physics creativity project is an approach that combines theoretical and practical aspects of learning physics. In this project, pre-service physics teachers s are not only required to master physics concepts but are also invited to apply their knowledge in real-world situations. One of the key factors in the success of a physics creativity project is pre-service physics teachers engagement in the learning process. Pre-service physics teachers engagement, or what is often referred to as pre-service physics teachers engagement, includes pre-service physics teachers s' active participation in cognitive, emotional, and behavioral learning activities. When pre-service physics teachers s are actively engaged, they tend to be more motivated to learn and have a deeper understanding of the material being studied (Ciriello et al., 2024; Ivcevic & Grandinetti, 2024).

Pre-service physics teachers engagement in physics creativity projects is also influenced by the quality of the content provided by the teacher. Relevant, engaging, and contextual content can help pre-service physics teachers s understand how physics concepts apply in everyday life. On the other hand, if the content presented is too abstract or irrelevant to pre-service physics teachers s' daily experiences, they will have difficulty understanding and applying the concept. Therefore, teachers need to design physics creative projects that focus on theoretical concepts and provide opportunities for pre-service physics teachers s to explore and create creative solutions based on their physics knowledge (Grey & Morris, 2024a; Strobel et al., n.d.).

In addition to pre-service physics teachers engagement and learning content, numeracy literacy also plays a vital role in the success of physics creativity projects. Numeracy literacy helps pre-service physics teachers s interpret data, calculate, and present information quantitatively. In the context of physics learning, numeracy literacy functions to solve physics problems and understand natural phenomena that can be measured and analyzed numerically (Deng & Gao, 2023; Grey & Morris, 2024b; Strobel et al., n.d.). For example, in a physics project involving the motion of objects, pre-service physics teachers s must be able to measure distance, speed, and acceleration and relate them to physics concepts such as Newton's laws. Pre-service physics teachers s will struggle to complete the project well without adequate numeracy literacy skills.

Engagement refers to the level of engagement, interest, and emotional connection an individual or group has with a particular activity, event, or topic. This can be manifested in various forms, such as attention, participation, enthusiasm, and dedication.' Researchers have investigated aspects of pre-service physics teachers engagement in multiple contexts and their importance in the teaching and learning process. Pre-service physics teachers engagement has attracted research interest in understanding educational outcomes, dropout behavior, and lack of motivation among pre-service physics teachers s. Interactive engagement has proven to be critical for pre-service physics teachers s to develop conceptual understanding (Consoli et al., 2024; Samaila & Al-Samarraie, 2024). Additionally, continued pre-service physics teachers engagement in the form of retention is considered a desirable outcome of education itself.

Emotional and cognitive aspects of engagement in schoolwork—how pre-service physics teachers s behave, feel, and think. This classification is used in this work in interpreting teachers' statements. The most directly noted by teachers is behavioral engagement, frequently mentioned in observational engagement studies. Emotional engagement can extend to behavioral engagement but is usually studied using self-reports. Pre-service physics teachers s in four junior high school classes self-evaluated their engagement after each lesson for a week; they found significant variations, not only between pre-service physics teachers s but also between school subjects, with the highest levels of engagement in non-academic classes. These results illustrate the challenges faced, e.g., by science teachers. Many teachers in their research were initially unaware of the cognitive engagement of quiet pre-service physics teachers s (Consoli et al., 2024; Samaila & Al-Samarraie, 2024).

Teachers can exploit pre-service physics teachers s' interests in various ways. First, teachers can provide opportunities for pre-service physics teachers s to express their interest in science. Second, teachers can use coercion elements in teaching that are intended to arouse pre-service physics teachers s' interest in something. This is often referred to as situational interest. Research partnerships that develop project-based learning units can increase situational engagement in science classrooms. The teacher can control situational interest, which can lead to the development of individual interests and improved learning. Therefore, using triggers or hooks to create situational interest and pre-service physics teachers' engagement is an essential tool for teachers (Nyirahabimana et al., 2024; Tschisgale et al., 2024a).

The relationship between engagement, content, and numeracy literacy in physics learning is an important issue that needs to be considered to improve the quality of physics education in Indonesia. Increasing pre-service physics teachers' engagement through creative projects, providing relevant and contextual content, and strengthening pre-service physics teachers' numeracy literacy skills is hoped to make physics learning more enjoyable, meaningful, and effective (Consoli et al., 2024; Kaya et al., n.d.). However, to date, little research specifically examines the relationship between engagement, content, and numeracy literacy in the context of physics creativity projects. Therefore, this study explores further how pre-service physics teachers' engagement, content quality, and understanding of numeracy literacy play a role in the success of physics creativity projects. This research focuses on three key points:

(1) How is pre-service physics teachers' engagement in physics creativity projects?
(2) How do the interactions between pre-service physics teachers' engagement, physics content understanding, and numeracy literacy support the success of physics creativity projects?
(3) How do pre-service physics teachers s perceive the role of engagement, content, and understanding of numeracy literacy in physics creativity projects?

2. Method

This research employed a mixed-method approach with an explanatory design. A quantitative approach used a quasi-experimental method with a pretest-posttest control group design. The study involved purposive sampling of 38 pre-service physics teachers enrolled in environmental physics courses at a university in a small region of Indonesia, comprising 16 pre-service physics teachers s in the experimental group and 12 pre-service physics teachers s in the control group. A qualitative approach used qualitative description with an observation sheet for physics creativity project-based learning. One of the main limitations of this study is the relatively small sample size (N = 38). While the findings provide valuable insights into the role of engagement, content, and numeracy literacy in physics creativity projects, the limited number of participants may affect the generalizability of the results. A larger sample size could provide more robust statistical power and increase the reliability of the conclusions. Future research should consider expanding the sample to include a more diverse group of pre-service physics teachers to enhance the applicability of the findings to a broader population.

A mixed-method approach with an explanatory design in the context of physics creativity project-based learning involves integrating quantitative and qualitative data to provide a comprehensive understanding of pre-service physics teachers s' numeracy literacy (Gillespie et al., 2024). In this approach, the initial phase involves quantitative data collection, such as pretest and post-test scores, to measure the effectiveness of physics creativity project-based learning on pre-service physics teachers s' numeracy literacy outcomes. After gathering and analysing quantitative results, qualitative approaches, such as observation, explain and add depth to the findings, providing insights into how pre-service physics teachers s interact with project- based activities, their engagement levels, and the specific skills they develop. Validity in the Rasch Model can be assessed using Item Fit Statistics, including Infit MNSQ (1.02) and Outfit MNSQ (1.05). Items are considered fit if Infit MNSQ and Outfit MNSQ are within the acceptable range of 0.5 – 1.5. Reliability in the Rasch Model is analyzed through Person Reliability (0.81), Item Reliability (0.89), Person Separation Index (2.75) and Item Separation Index (3.5). Most items align well with the Rasch Model, though some require revision due to misfit. The test demonstrates good to excellent reliability, ensuring consistent measurement of numeracy literacy.

This design provides statistical evidence of the effectiveness of the physics creativity project and qualitative insights into pre-service physics teachers s' perceptions, challenges, and creative processes. Ultimately, the explanatory mixed-method approach enriches the analysis of physics creativity project-based learning impact, showcasing measurable numeracy literacy outcomes along with various learning experiences that contribute to them.

The implementation of this research involves two groups: an experimental group and a control group. The experimental group engages in physics creativity project-based learning, while the control group uses inquiry-based learning. The steps are as follows:

1. Implement different instructional activities in both groups.
2. Conduct a pretest on numeracy literacy at the beginning of the learning process.
3. Deliver physics creativity project-based learning to the experimental group over three sessions, while the control group receives inquiry-based learning.
4. Administer a posttest to all experimental and control group pre-service physics teachers s to assess numeracy literacy.
5. Analyze posttest results to map out pre-service physics teachers s' numeracy literacy.
6. Analyze observations of pre-service physics teachers s' learning activities and assess their performance reports.
7. Compare numeracy literacy levels between the two groups.

Figure 1 The research flows with Quantitative Data Collection to gather measurable data, often through pretests and posttests, assessing the impact of physics creativity project-based learning on pre-service physics teachers' numeracy literacy. After collecting and analyzing this quantitative data, Qualitative Data Collection follows, such as observations or interviews, to provide a deeper, context-based understanding of pre-service physics teachers s' experiences and interactions within learning activities (Creswell, 2017). The research flow can be seen in Figure 1.

Integrating Quantitative & Qualitative findings allows both data types to be analyzed side-by-side, uncovering relationships and offering insights that pure quantitative or qualitative data alone might overlook. In this phase, qualitative data help explain or contextualize quantitative trends, such as variations in test scores or engagement levels, by identifying themes related to pre-service physics teachers perceptions, creative processes, or engagement challenges.

In the Discussion and Implications Phase, researchers present integrated findings addressing measurable outcomes and in-depth qualitative insights. These insights are used to make practical recommendations for improving creativity in project-based learning. Implementation highlights its implications for pre-service physics teachers s' numeracy literacy and offers suggestions for broader application. Through this structured integration and discussion, the findings provide a robust basis for understanding the effectiveness and experiential impact of the creativity project-based learning approach, supporting evidence-based adjustments and innovations in STEM education practices.

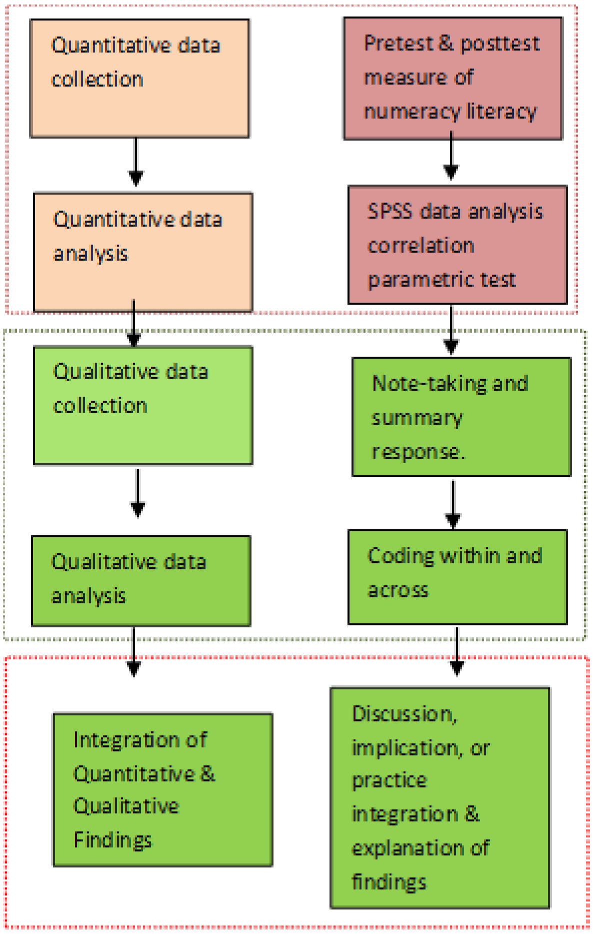

Figure 1. The research flow

Data was collected through various instruments, including knowledge test sheets with essay questions, observation sheets for lecture program implementation, and product assessment rubrics. The subsequent phase focused on qualitative data collection through observation and questionnaires to explain the quantitative findings. Quantitative learning outcome data were analyzed using the Wilcoxon test, effect size calculations, and N-gain analysis, while qualitative data were analyzed descriptively.

3. Results and Discussion

The results of this study illustrate the role of engagement, content, and understanding of numeracy literacy in physics creativity projects. Themes raised in pre-service physics teachers s' descriptions of engagement. Several pre-service physics teachers s described engagement as an individual state connected to science content and synonymous with interest, as in Figure 2.

Figure 2 shows the perception of engagement with a maximum score of 3 and a minimum score of 0 for each group of 3 pre-service physics teachers s. The results of perceptions of pre-service physics teachers engagement were obtained by group C, with an average perception of engagement of 2.6. The indicator of perceived pre-service physics teachers engagement is 2.8 on the lack of engagement indicator.

Several forms of pre-service physics teachers engagement are interest in science, values, hopes, individual interests, and learning activities. Each group shows pre-service physics teachers participation in learning activities; pre-service physics teachers s ask questions and discuss with peers. Observation results record pre-service physics teachers behavior and attitudes through expressions of learning engagement in class. Engagement in discussions shows pre-service physics teachers s' ability to collaborate and problem-solving abilities so that pre-service physics teachers s can connect new knowledge with previous knowledge. The role of pre-service physics teachers engagement in the group is shown in Figure 3.

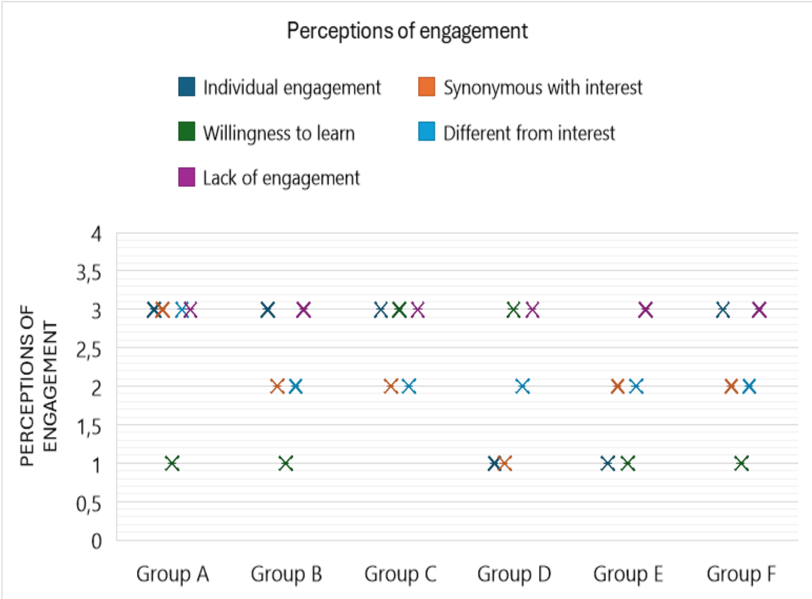

Figure 2. Perceptions of pre-service physics teachers engagement

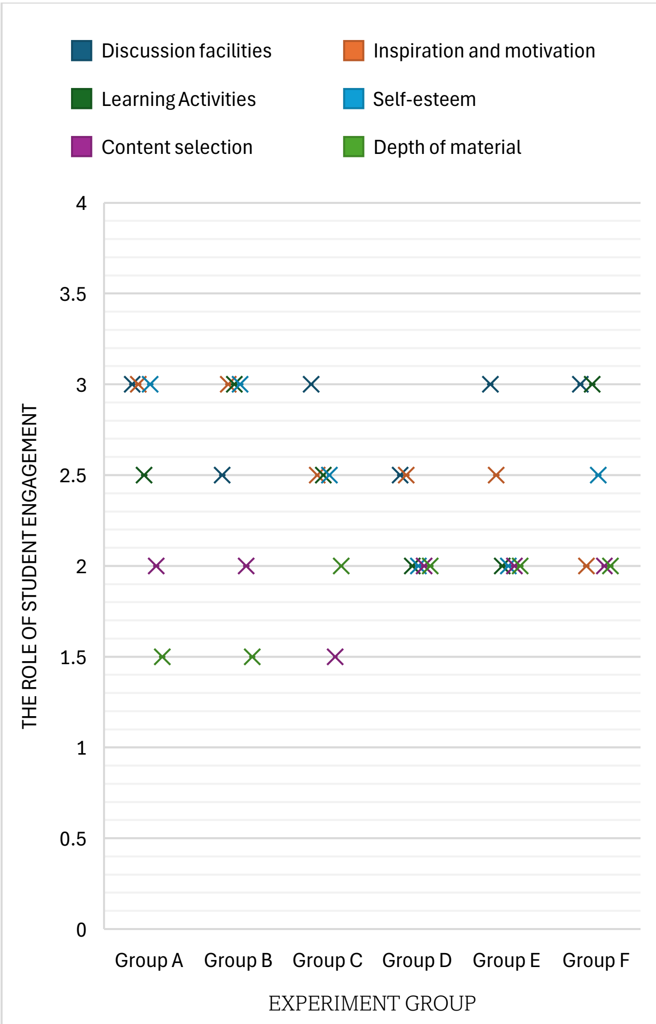

Figure 3. The role of pre-service physics teachers engagement in each group

Each group can utilize the role of engagement in each stage of learning activities. Discussion facilities are an indicator of achievement in the highest category. The depth of the material can only be achieved by each group but is still relatively low. Descriptives of pre-service physics teachers engagement in discussions and learning physics are shown in Table 1.

Table 1. Descriptives of pre-service physics teachers engagement in discussions and learning physics

Pre-service physics teachers engagement in learning physics	Group
Determine the theme of the creative idea	A, C
Constructing deep understanding	B, F
Apply scientific methods and experiments	A, D
Involving pre-service physics teachers activity	E
Arouse high curiosity	D, E
Demonstrate interest and understanding	A, C, D
Forming variations in learning strategies	C, F
Increase creativity	A, D

Pre-service physics teachers engagement in discussions and physics learning activities is more active, namely in group D; pre-service physics teachers engagement has four components. Group A and Group C achieved three engagement components in learning activities and discussions. Group E and Group F are only two components of pre-service physics teachers engagement. Group B was the group that completed the lowest level of only one element of pre-service physics teachers engagement.

Pre-service physics teachers engagement in discussions and physics learning activities is more active, namely in group D; pre-service physics teachers engagement has four components. This group shows high engagement, is active in discussions, shows high curiosity, and can apply scientific methods effectively. Group A and Group C achieved three engagement components in learning activities and discussions. These two groups engage well, but it is not optimal. Pre-service physics teachers s are active in several aspects, such as discussing creative ideas and experimentation, but need to improve in building understanding and creativity. Pre-service physics teachers s only participate in one aspect of learning. Pre-service physics teachers s in this group require intensive guidance to increase participation. Implementing various learning strategies such as simulations, interactive experiments, and structured discussions can help all groups achieve maximum engagement.

This research uses a numeracy literacy test—Pretest for pre-service physics teachers s before learning Physics Creativity Projects. The posttest after the intervention, the normality test, and the homogeneity test on the pretest and posttest analysis were carried out, as shown in Table 2.

Table 2. Descriptive Results of the Shapiro–Wilk of normality and homogeneity test

Group	W	df	Sig.	Distribution
Experiment	Shapiro-Wilk			
Pretest	0.48	21	0.35	Normal
Posttest	0.46	21	0.34	Normal
Control	Shapiro-Wilk			
Pretest	0.59	18	0.41	Normal
Posttest	0.57	18	0.52	Normal
Levene Statistic				
	Lev Stat	df1	df2	
Pretest	1.32	21	21	Homogenous
Posttest	1.36	18	18	Homogenous

Statistical tests depend on the evaluation results in data normality based on Basic principles to determine if they can be applied to parametric or non-parametric tests. The Shapiro–Wilk test was applied to the samples with a small sample size, under 50. The Shapiro–Wilk test can also be applied to a larger sample. The null hypothesis states that the data has been collected from a normally distributed population. When $p > 0.05$, the null hypothesis is accepted, and the data is in the normally distributed category. The results in Table 2 show that this data is usually distributed: $p = 0.35$, p =

0,41 for the pretest, p = 0.34, and p = 0,52 for the posttest. Therefore, the specified parameter test is applied in hypothesis analysis.

A descriptive and independent statistic sample t-test was applied to compare the results of the numeracy literacy pretest, as indicated in Table 3.

Table 3. The pretest independent *t*-test comparing the experimental and control groups

Data Description	Group	
	Experiment	Control
N	21	18
Max	10	10
Mean	25.61	28.04
t-value	0.783	
Sig. (2 tailed)	0.238	
Quality	No Significant	

An Independent t-test was applied to compare the results of the numeracy literacy posttest, as indicated in Table 4.

Table 4. The posttest independent t-test comparing the experimental and control groups

Data Description	Group	
	Experiment	Control
N	21	18
Max	10	10
Mean	79.85	50.42
t-value	2.417	
Sig. (2 tailed)	0.001	
Quality	Significant	

An Independent t-test was applied to compare the results of the numeracy literacy posttest, as indicated in Table 5.

Table 5. Results of independent t-test

Data Description	Group	
	Experiment	Control
N	21	18
Pretest	25.61	28.04
Posttest	79.85	50.42
t-value	3.544	
p-value	0.001	

This is done to determine whether Numeracy literacy between the experimental and control groups is comparable or not. Table 5 shows that p (0.341) was obtained exceeds 0.05, which means the test does not show statistical significance at the 0.05 level, indicating no significant difference between the two groups, and the null hypothesis was accepted for initial testing. In connection with the performance, no differences were seen between the experimental groups (M = 3.458, SD = 1.873) and the control group (M = 3.415, SD = 1.952) before intervention.

The analysis of the effectiveness of the physics creativity projects learning method reveals significant improvements in student engagement, content understanding, and numeracy literacy. Compared to traditional learning approaches, physics creativity projects fosters active participation, deeper conceptual comprehension, and stronger numerical reasoning by integrating real-world problem-solving and hands-on project development. The findings indicate that students involved in physics creativity projects demonstrate higher motivation, better retention of physics concepts, and improved ability to interpret and apply mathematical data. Additionally, the study provides a more in-depth discussion than previous research by highlighting the interconnected role of engagement, content mastery, and numeracy literacy in enhancing students' creativity and critical thinking skills. These insights suggest that physics creativity projects is an effective instructional approach that not only supports physics learning but also promotes STEM-related competencies, making it a promising model for future educational practices.

When determining the theme of a creative idea. Pre-service physics teachers s actively identify relevant themes from ideas developed creatively, individually, and in groups. This process involves critical thinking and the ability to relate physics concepts to real applications. Constructing in-depth understanding directs pre-service physics teachers s to build conceptual knowledge through theoretical and practical exploration of physics concepts. Applying scientific and experimental methods, pre-service physics teachers s show engagement by designing and carrying out experiments, analyzing data, and drawing conclusions (Hornburg et al., 2024; Tang, 2024; Tschisgale et al., 2024b).

Pre-service physics teachers activity can be seen from pre-service physics teachers s' active participation in discussions, asking questions, expressing opinions, and providing solutions to the physics problems being discussed. Pre-service physics teachers s' curiosity is reflected in their enthusiasm for learning about physical phenomena and answering in-depth questions about the concepts being taught. Pre-service physics teachers s show interest through positive responses to learning material and are able to explain physics concepts clearly. Practical group discussions create various strategies, such as interactive discussions, learning media, and simulations. Pre-service physics teachers engagement encourages creativity in solving problems or designing simple experimental tools that support physics learning. Pre-service physics teachers s focus on content according to scientific principles, avoid misconceptions, and understand correctly (Firetto et al., 2024).

Pre-service physics teachers engagement in this pre-service physics teachers creativity project is one of the key factors influencing learning effectiveness. Pre-service physics teachers engagement is divided into three main dimensions: cognitive, emotional, and behavioral. Cognitive engagement refers to pre-service physics teachers s' mental effort to understand the learning material. Emotional engagement reflects pre-service physics teachers s' feelings toward the learning process, whether they feel happy, interested, or emotionally connected to the material being studied. Meanwhile, behavioral engagement refers to pre-service physics teachers s' physical participation in learning activities, such as actively asking questions, discussing, or completing assignments (Kaplan Mintz et al., 2023; Rosenberg et al., 2023; Sokha, 2024).

In the context of a physics creativity project, pre-service physics teachers engagement is crucial because this project requires pre-service physics teachers s to think critically, be creative, and work collaboratively. Pre-service physics teachers s actively engaged in the project are more likely to connect physics concepts with their practical applications, enabling them to complete the project more effectively. On the other hand, pre-service physics teachers s with low engagement tend to struggle to understand and complete the project. These pre-service physics teachers s often lack the motivation and skills to involve themselves in learning actively (Staberg et al., 2023).

When determining the theme for creative ideas, pre-service physics teachers s actively identify relevant themes from ideas developed creatively, individually or in groups. This process involves critical thinking and the ability to connect physics concepts with real-world applications. In constructing a more profound understanding, pre-service physics teachers s are guided to build conceptual knowledge through theoretical and practical exploration of physics concepts, applying scientific and experimental methods. Furthermore, pre-service physics teachers projects can enhance their problem-solving abilities. Pre-service physics teachers s taught using various creative steps in project completion demonstrate improved problem-solving skills by recognizing and evaluating relevant information, selecting appropriate equations or diagrams, and using suitable problem-solving techniques (Li et al., 2023).

Pre-service physics teachers s can understand complex relationships, integrate abstract mathematical concepts with practical applications, and gain a more comprehensive understanding of mechanical principles through interactions in studying content and developing numeracy literacy understanding. This enhanced understanding can aid in long-term memory retention and information transfer, enabling pre-service physics teachers s to apply their knowledge to novel problem-solving situations. The use of diverse pre-service physics teachers engagement strategies in problem-solving learning can reduce cognitive load by offering multiple ways to understand the same concept. These findings are consistent with other studies that emphasize the importance of diverse approaches in enhancing pre-service physics teachers s' problem-solving skills (Fredagsvik, 2023).

The content presented in physics learning also significantly influences pre-service physics teachers engagement and their understanding of physics concepts. Engaging, relevant, and contextual content can help pre-service physics teachers s comprehend how physics concepts apply to everyday life. For instance, in a physics creativity project involving the creation of an automatic plant watering device, pre-service physics teachers s can learn about electrical and fluid mechanics concepts in a context that relates to their daily lives. Such relevant content can enhance pre-service physics teachers s' interest in the subject matter and encourage them to engage more actively in learning (Kaplan Mintz et al., 2023; Sokha, 2024). However, the content must also be tailored to the pre-service physics teachers 's level of understanding. Pre-service physics teachers s may struggle to grasp and apply the concepts in their creativity projects if the content is too complex or abstract. Therefore, teachers must design learning content that aligns with pre-service physics teachers s' abilities while challenging them to think critically and creatively (Fakaruddin et al., 2024).

Numeracy literacy is a fundamental skill essential for learning physics. It not only encompasses the ability to perform calculations but also the ability to interpret data, make estimations, and present information quantitatively (Taş & Minaz, 2024). In physics creativity projects, numeracy literacy is crucial in helping pre-service physics teachers s solve quantitative physics problems, such as calculating speed, acceleration, force, or energy. Good numeracy literacy skills enable pre-service physics teachers s to complete projects more efficiently and accurately. Conversely, pre-service physics teachers s with low numeracy literacy may struggle to finish projects because they cannot correctly interpret data or perform accurate calculations. Therefore, one of the objectives of physics creativity projects is to strengthen pre-service physics teachers s' numeracy literacy through practical activities that involve calculations and data analysis (Erdem, 2024).

Moreover, using various scientific procedures in creative projects helps pre-service physics teachers s develop problem-solving skills and improve their performance. Diagrams and graphs' visual and tangible nature help make abstract ideas more concrete, capture pre-service physics teachers s' attention, and encourage active engagement (Öz, 2024; Staberg et al., 2023). Pre-service physics teachers s' active participation in learning positively impacts their academic performance and overall learning outcomes.

It is important to note that the positive effects of various creative activities on academic achievement are evident across the entire group of pre-service physics teachers s, not just those with high academic performance. This finding suggests that pre-service physics teachers s with varying levels of prior knowledge and cognitive abilities can benefit from including various project-based activitie (Li et al., 2023; Staberg et al., 2023)s. The success of these projects promotes a learning environment that is inclusive, addressing the diverse needs of engineering pre-service physics teachers s by responding to different learning styles and preferences. Pre-service physics teachers s will develop critical thinking skills and essential active learning competencies using this method.

4. Conclusion

The study highlights engagement, content knowledge, and numeracy literacy understanding, which significantly foster creativity in physics projects. Qualitative data demonstrated that pre-service physics teachers s' active engagement and deep understanding of content were crucial in enhancing their creative output in physics-related tasks. The quantitative analysis, utilizing the Wilcoxon test, effect size, and N-gain analysis, also revealed positive improvements in learning outcomes. This suggests that integrating numeracy literacy with active engagement in content can substantially contribute to pre-service physics teachers s' creative development in physics projects. Qualitative and quantitative findings emphasize the importance of a holistic approach in nurturing creativity through comprehensive engagement and content mastery.

In physics education, pre-service physics teachers engagement, content quality, and numeracy literacy are three interrelated factors influencing the success of physics creativity projects. Pre-service physics teachers engagement in projects can increase their motivation to learn and deepen their understanding of physics concepts. Relevant and contextual content can help pre-service physics teachers s connect physics concepts to real-world situations, making them more interested in studying the material. Numeracy literacy is also crucial in assisting pre-service physics teachers s in interpreting data, performing calculations, and solving quantitative physics problems. By strengthening pre-service physics teachers engagement, providing quality content, and improving numeracy literacy, physics learning is hoped to become more effective and meaningful for pre-service physics teachers s. This research is expected to provide new insights into the role of engagement, content, and numeracy literacy in the success of physics creativity projects and offer recommendations for educators in designing more effective and engaging physics lessons.

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All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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