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Exploring Project-Based Learning: Physics E-Posters in Pre-Service Science Education

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Abstract

This study investigates the implementation of project-based learning, explicitly focusing on designing and presenting e-posters within the Basic Physics course for pre-service science teachers, with a particular emphasis on pre-service biology teachers. Descriptive and correlational quantitative methods were utilized to analyze data collected from 16 participating students throughout 16 sessions. The assessment perspectives of lecturers, peers, and self-assessment were examined, revealing disparities in scores and highlighting the importance of multiple assessment sources. Recognition through awards was granted to students with exemplary performance, while guidance sessions led by the instructor significantly correlated with improvements in poster design. Analysis of poster content indicated a focus on fundamental physics concepts, mainly mechanics, with students utilizing various information sources. The study underscores the effectiveness of project-based learning in promoting student engagement, skill development, and conceptual understanding in physics education.

INTRODUCTION

Physics is the most fundamental discipline in science, serving as the cornerstone of scientific inquiry upon which many other disciplines rely. For pre-service science teachers, a foundational understanding of physics is essential [1], as it provides the necessary framework for comprehending complex scientific phenomena [2]. However, teaching physics to this demographic demands a nuanced approach, recognizing these students' diverse backgrounds and future professional needs. Particularly for pre-service biology teachers, an introductory physics course suitable to the needs of biology students is crucial to engage their interest effectively [1].

Designing a Basic Physics Course for pre-service science teachers requires carefully considering several key factors. Firstly, the course must cater to the unique characteristics of science topics, ensuring relevance and applicability across various scientific disciplines such as Chemistry, Biology, Earth Science, and Astronomy. Recognizing that different disciplines perceive the world through distinct lenses underscores the necessity of customizing the physics curriculum to meet the specific requirements of science students [1], especially pre-service biology teachers. Secondly, the course must also encourage pre-service teachers to adapt to various future challenges in the education world.

Pre-service science (biology) teachers face various challenges as they prepare for their careers, including instructional media design, technology integration, and content presentation. The rapid advancement of science and technology is a fundamental reason for the emergence of challenges in education [3]. Moreover, it's essential to recognize the diverse levels of comfort with mathematics among pre-service science students. Although many physics concepts inherently involve mathematical principles, biology students, on average, demonstrate lower proficiency and comfort with mathematics than their engineering and physical science counterparts. [1], [4]. Therefore, a practical Basic Physics Course should aim to minimize mathematical complexities while highlighting authentic scientific or biological applications to engage students effectively.

In pursuit of fostering active engagement and meaningful learning experiences, innovative pedagogical approaches such as active learning [5] and project-based learning [6] hold considerable promise. Active learning methodologies empower students to construct knowledge actively by integrating new information with their existing understanding, facilitating deeper comprehension and retention. This principle implies that assessments should enable students to actively generate meaning by connecting new information to their existing experience. Besides knowledge enhancement, the development of skills is also crucial in learning. Creativity and scientific communication skills are precious for undergraduate students, particularly for future pre-service science teachers. Project-based learning offers an avenue to foster creativity and enhance scientific communication skills. For instance, involving students in designing and presenting posters about content learning can facilitate the development of these skills [7], [8].

Designing posters allows students to represent scientific understanding in diverse forms and provide a more comprehensive representation of ideas through illustrations than written explanations [6]. Poster presentations are a commonly used format for sharing information in academic settings. They have successfully increased knowledge, changed attitudes, and influenced behaviour when integrated with a range of educational interventions [9]. Posters are significant in middle and high school science classrooms [10] and teacher education [11]. Students develop representations, such as posters, for various physics concepts. Creating posters solidifies students' learning, and conveying ideas and findings to others helps them build a robust and interconnected comprehension of related scientific concepts that can be applied in different situations [6], [12]. Posters also can represent students' mental models and initial understanding of a concept [13]. As pre-service science teachers, having experience designing and presenting scientific concepts in the form of posters is essential.

As previously highlighted, the presence of technology stands as a significant challenge in the field of education. Adapting to technology has become a crucial skill in today's era [14]. When effectively adopted, technology can be integrated into various other aspects, including pedagogical approaches and learning content [15]. Technologies could be used as tools to design and present posters. Integrating technology, such as tools like Photoshop, Canva, and other applications, can enhance this experience [16]. Integrating computer and information technology with poster presentations is still relatively new, with limited innovations that promote a learner-centred and active educational approach [9]. The potential of technology is vast, offering opportunities to connect with a global audience and facilitating collaboration. A one-to-one technology program can empower students to collaborate effectively on projects [16].

This study aims to address these challenges and bridge the gap in physics education for pre-service science teachers by integrating project-based learning into the Basic Physics Course. Specifically, the focus will be designing and presenting e-posters about physics concepts using technological tools like Photoshop and Canva. By embracing innovative pedagogies and leveraging technology, we endeavour to equip pre-service science teachers with the necessary knowledge, skills, and competencies to excel in their future careers.

METHOD

Descriptive and correlational quantitative methods were employed in this study, which integrated project-based learning into the Basic Physics course for pre-service science teachers, with a particular focus on pre-service biology teachers. Sixteen students participated, and all were involved in the research subject. The course activities spanned 16 sessions, including mid-semester and end-ofsemester examinations. Project-based learning activities replaced the mid-semester exam, with students creating digital or electronic posters (e-Posters) on physics concepts and presenting their ideas to instructors and peers.

Each student is responsible for designing physics e-posters and has to present the ideas contained within the posters. The presentation sessions are also followed by discussions involving course instructors and peers. Questions related to the presented posters can be posed to start a conversation. Data were collected through project assessment using the e-Poster Assessment Form (Table 1), which comprised indicators for design (content, aesthetics, originality) and presentation (fluency, accuracy, confidence).

Table 1. e-Poster Assessment Form

No	Name	e-Poster Design			e-Poster Presentation			Additional Notes
		Content	Aesthetics	Originality	Fluency	Accuracy	Confident	
1	Student 1							
2	Student 2							
3	Student 3							
…	…							

Three different sources were used to conduct the assessment: by the lecturer (lecturer assessment), by peers (peer assessment), and by oneself (self-assessment). The lecturer provided evaluations based on the assessment form, while students also assessed their peers' posters for design and presentation. Additionally, students conducted self-assessments. Data from all three assessors were collected, with scores ranging from 0 to 100.

Descriptive statistics were utilized to analyze e-Poster scores, providing insights into project-based learning outcomes. A comprehensive understanding of the project-based learning outcomes was attained using descriptive statistics, encompassing various assessment categories, indicators, and assessors. This approach facilitated the examination of central tendencies, variability, and distributions of scores across different dimensions, thereby offering valuable insights into the effectiveness of the instructional intervention. Furthermore, correlation tests were performed to explore relationships between poster design, presentation, and different assessors and the impact of guidance frequency on poster scores. Correlation tests help to examine the degree of association between average, design, and presentation scores from different assessors (lecturer, peers, and self-assessment). Similarly, correlations between different assessors' scores can provide insights into the consistency or agreement among their evaluations. Through the integration of descriptive statistics and correlation tests, this research seeks to elucidate the impact of project-based learning on developing essential skills and competencies among pre-service science teachers.

Furthermore, recognition fostered motivation, with awards for best design, presentation, and e-poster. Motivation plays an achievement drive in learning science [17]. Motivation is an essential aspect for students to finish the project. The best design is determined based on accumulating all scores in the design category. Similarly, the best presentation is determined based on accumulating all scores in the presentation category. Finally, Student feedback regarding project-based learning was collected through structured questions administered by the instructor after project completion. Ethical considerations were taken into account, with informed consent obtained from all participants and protocols followed to ensure confidentiality and data protection throughout the study.

RESULT AND DISCUSSION

The results of the data analysis were descriptively presented from two perspectives: the assessors (lecturer, peer, and self-assessment) and the score categories (design and presentation). The average values are represented in the diagram as shown in Figure 1, and the detailed results of descriptive statistics are shown in Table 2.

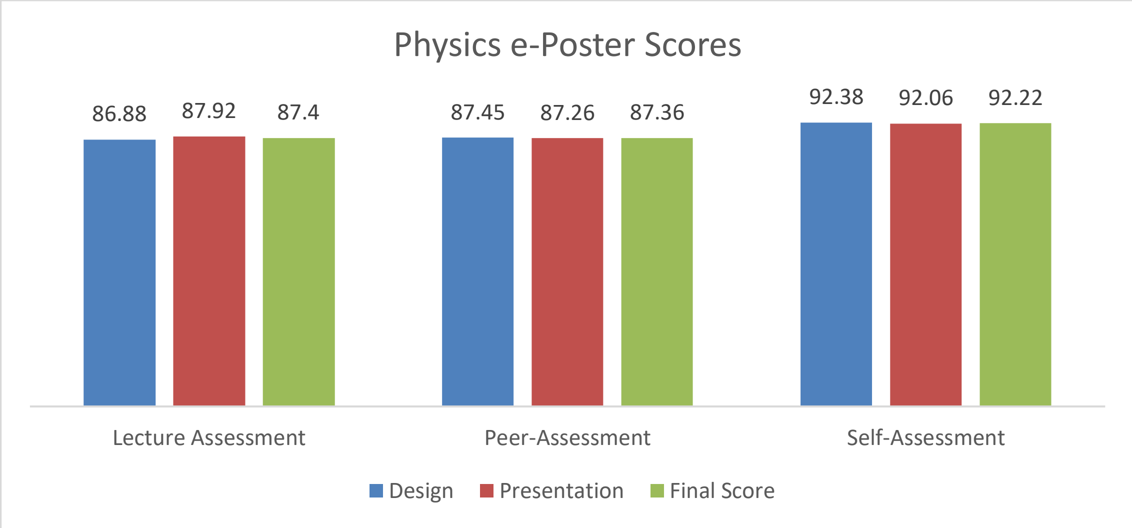

Figure 1. Physics e-Poster Scores

Table 2. Descriptive Statistic Results

Data	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	
							Statistic	Std. Error
Lecturer (Design)	18.33	76.67	95.00	86.88	4.03	16.25	-0.554	0.564
Lecturer (Presentation)	25.00	75.00	100.00	87.92	8.09	65.37	0.270	0.564
Lecturer (Average)	**19.17**	**75.83**	**95.00**	**87.40**	**5.55**	**30.74**	**-0.188**	**0.564**
Peer (Design)	8.86	81.27	90.13	87.46	1.99	3.98	-1.930	0.564
Peer (Presentation)	13.80	78.93	92.73	87.26	3.78	14.29	-0.566	0.564
Peer (Average)	**10.97**	**80.10**	**91.07**	**87.36**	**2.63**	**6.91**	**-1.281**	**0.564**
Self (Design)	30.00	70.00	100.00	92.38	9.10	82.78	-1.450	0.564
Self (Presentation)	30.00	70.00	100.00	92.06	8.58	73.66	-1.740	0.564
Self (Average)	**30.00**	**70.00**	**100.00**	**92.22**	**8.19**	**66.99**	**-1.710**	**0.564**
All Design	18.40	76.25	94.65	88.09	4.15	17.23	-1.618	0.564
All Presentasi	22.84	74.79	97.63	88.61	6.37	40.61	-0.253	0.564
Average All	**18.51**	**75.52**	**94.03**	**88.35**	**4.80**	**23.04**	**-1.249**	**0.564**

From the perspective of assessors (lecturer-, peer-, and self-assessment), students tended to rate themselves with higher scores, with an average self-assessment score of 92.21, significantly higher than scores from peers (87.36) and instructors (87.40). Suggests a potential lack of objectivity in self-assessment practices, which is consistent with existing literature [18]. Notably, while there was a general tendency for higher self-assessment scores, some students assigned themselves lower scores (70.00), indicating a degree of self-awareness and critical reflection.

Peer assessments exhibited similar scores, as reflected by minor standard deviations, while lecturer assessments showed more significant variability. This variability is supported by the skewness data, indicating a distribution closer to normal for lecturer assessments (skewness statistic that is closest to 0). On the other hand, peer assessment was affected by students' initial resistance to participate in transparency and honesty [19]. The distribution of scores from the three different assessors for each student is illustrated in Figure 2.

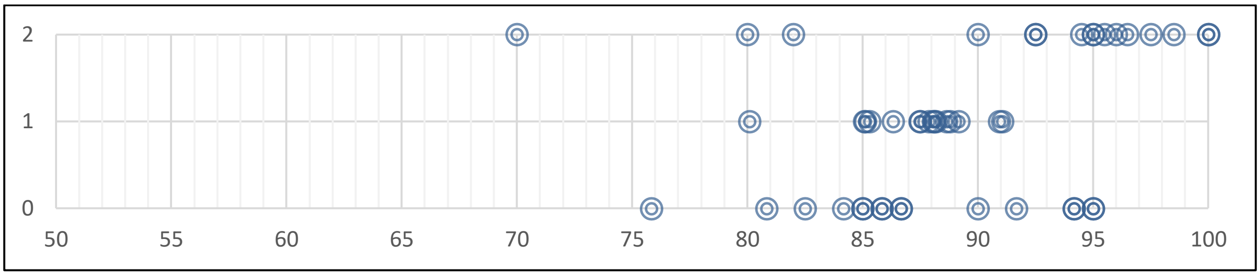

Figure 2. Students e-poster score distribution: lecturer (0), peer (1), and self-assessment (2)

The score discrepancy among assessors highlights the importance of incorporating multiple assessment sources to understand student performance [18] comprehensively. Despite encountering challenges and obstacles in peer and self-assessment, the accuracy and benefits of these assessments can be enhanced through various means. One such method is the utilization of more detailed rubrics [18], [20] and repeated practice in providing assessments with guidance from instructors [19].

Subsequently, correlation tests are conducted for various available data sets, as shown in Table 2. The descriptive analysis indicates that most data is not normally distributed, indicated by skewness statistics values outside the range of -1 to 1. From the assessors' perspective, only the scores from the lecturer assessment exhibit a normal distribution. Consequently, the relationship or correlation analysis uses Spearman's rho test [21]. The correlation test results are presented in Table 3-5.

Table 3. Correlation Test Results: Average Scores

Data	Test	Lecturer (Average)	Peer (Average)	Self (Average)
Lecturer (Average)	Correlation Coefficient	1.000	**0.735***	0.279
	Sig. (2-tailed)	.	**0.001**	0.296
Peer (Average)	Correlation Coefficient	**0.735***	1.000	0.209
	Sig. (2-tailed)	**0.001**	.	0.437
Self (Average)	Correlation Coefficient	0.279	0.209	1.000
	Sig. (2-tailed)	0.296	0.437	.

*__Correlation is significant at the 0.01 level (2-tailed)__

Table 4. Correlation Test Results: Design Scores

Data	Test	Lecturer (Design)	Peer (Design)	Self (Design)
Lecturer (Design)	Correlation Coefficient	1.000	0.396	0.361
	Sig. (2-tailed)	.	0.129	0.170
Peer (Design)	Correlation Coefficient	0.396	1.000	0.341
	Sig. (2-tailed)	0.129	.	0.196
Self (Design)	Correlation Coefficient	0.361	0.341	1.000
	Sig. (2-tailed)	0.170	0.196	.

Table 5. Correlation Test Results: Presentation Score

Data	Test	Lecturer (Presentation)	Peer (Presentation)	Self (Presentation)
Lecturer (Presentation)	Correlation Coefficient	1.000	**0.869***	0.367
	Sig. (2-tailed)	.	**0.000**	0.162
Peer (Presentation)	Correlation Coefficient	**0.869***	1.000	0.332
	Sig. (2-tailed)	**0.000**	.	0.210
Self (Presentation)	Correlation Coefficient	0.367	0.332	1.000
	Sig. (2-tailed)	0.162	0.210	.

*__Correlation is significant at the 0.01 level (2-tailed)__

Design. Based on the results in Table 4, we can conclude that the design scores from the lecturer do not correlate significantly with the design scores from peers and self-assessment, as is the case between peers and self-assessment. Posters are designed to visually represent an issue that first attracts attention [9]. Regarding the statement about posters needing additional sources of information to be effective, it's noted that some students utilize the internet (physics web and YouTube) to search for content-related information for their posters. In contrast, others rely on physics books as their primary sources of information. Analysis of poster content revealed that most students focused on fundamental physics concepts, mainly mechanics, reflecting the foundational nature of these concepts in physics education [22], [23]. Students choose mechanics concepts such as free fall motion, Newton's law, gravitation, eclipse, energy, and momentum. Other students choose content about fluids, thermodynamics, waves, electromagnetic, and nuclear.

Designing a poster as a learning project in an introductory physics course aims to give simple explanations of basic physics concepts. The poster design process could start after the discussion about the course and project in the first lecture session and continue until the seventh session before the midterm exam (poster presentation) in the eighth session. Each student has approximately six weeks to work on their poster designs. Students are also allowed to engage in discussions or receive guidance from the instructor regarding poster design improvements before the submission and presentation deadline. As an additional analysis, a mapping of the frequency of guidance for each student and their poster scores in the design category provided by the instructor is conducted, as shown in Figure 3.

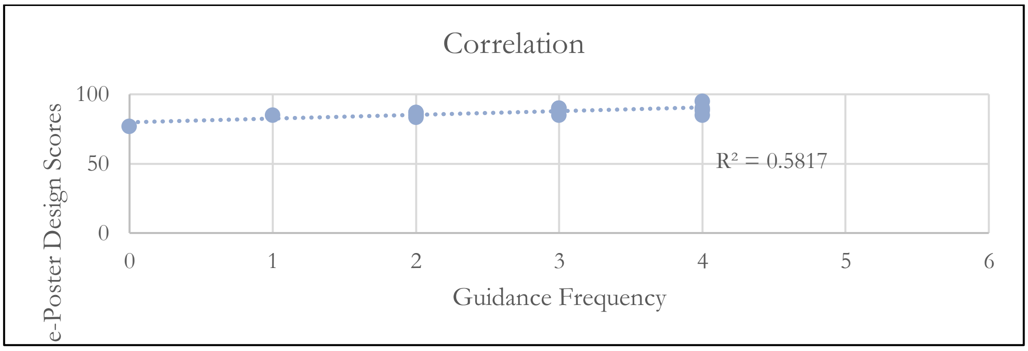

Figure 3. Correlation Between Guidance Frequency and e-Poster Design Scores

Table 6. Pearson Correlation Test Results

		e-Poster Design Scores	**Guidance Frequency**
e-Poster Design Scores	Pearson Correlation	1	0.763**
	Sig. (2-tailed)		0.001
Guidance Frequency	Pearson Correlation	0.763**	1
	Sig. (2-tailed)	0.001	

** Correlation is significant at the 0.01 level (2-tailed).

Guidance sessions provided by the instructor played a crucial role in facilitating poster design improvements. Correlation test results (Table 3) revealed a high and significant correlation between the frequency of guidance sessions and poster scores in the design category ($r = 0.763, \rho = 0.001$), indicating that more frequent guidance led to enhanced design quality—the importance of instructor support and feedback in fostering student learning and skill development.

Presentation. Based on the results in Table 4, we can conclude that the presentation scores from the instructor were found to have a significant correlation with the presentation scores from peers (r = 0.869 and ϱ = 0.000) but not with the presentation scores from self-assessment. Only two assessors (lecturer and peers) agree with the presentation score. Presenting ideas is an essential part of learning. Communicating ideas and findings to others helps students construct a solid, integrated understanding of related scientific ideas that they can use in other situations [6].

Physics e-posters are regarded as media that align with students' learning needs [24]. E-posters can be alternative learning tools to facilitate students' comprehension of scientific concepts [25]. Posters were intended to capture groups' evolving understanding of circuits as artefacts representing their mental models and provide information on the status of concepts, then promote conceptual change. In addition to being a project aimed at fostering creativity and communication, posters can be integrated into various science teaching strategies and approaches. For instance, creating posters can be part of science learning through modelling natural phenomena or experiments. Posters in this context are utilized to track the evolving understanding of concepts, particularly in areas like circuits, as they serve as artefacts representing students' mental models and provide insights into concept comprehension, potentially fostering conceptual change [13].

From a different perspective, the awards for best design, best presentation, and best e- were granted to students with the highest cumulative scores in each category. Notably, Student 5 received the best design award (94.65), and Student 13 received both the best presentation (97.64) and best e-Poster awards (94.03), showcasing exemplary performance in their respective areas. Recognition through awards acknowledges student achievements and serves as a motivating factor, aligning with the principles of achievement drive in science learning [26].

The findings from this research offer valuable insights that can significantly enhance project-based learning strategies and physics education for pre-service teachers. Firstly, the correlation between guidance frequency and poster scores highlights the critical role of instructor support and feedback in facilitating student learning and skill development. Educators can leverage this information to prioritize regular guidance sessions and provide constructive feedback to students throughout their project-based learning experiences. Additionally, the discrepancies observed in assessment scores among different assessors emphasize the importance of incorporating diverse assessment sources to understand student performance comprehensively. Educators can use this insight to implement a multi-faceted assessment approach, including self-assessment, peer assessment, and instructor assessment, to ensure a well-rounded evaluation of student learning outcomes.

Moreover, the focus on fundamental physics concepts in poster content underscores the foundational nature of these concepts in physics education. Educators can tailor their curriculum to emphasize these basic principles and provide additional resources and support to help students grasp these concepts effectively. By leveraging these findings, educators can refine their project-based learning strategies and curriculum design to create more engaging, effective, and inclusive learning experiences for pre-service science teachers.

Furthermore, designing and presenting posters was a valuable learning activity, promoting visual representation and communication of scientific ideas [6]. Poster design, drawings, and paintings allow students to represent scientific understanding in diverse forms, catering to visual/spatial learners [6]. The impact of designing posters as learning activities or projects on students' scientific knowledge and skills should be explored in greater detail. Poster designing could also be planned as a group activity in learning [13] to foster an interactive learning environment for students [9] or utilize other technological assistance such as posters equipped with videos [24], media social-based e-poster [25], and group poster in learning physics through play in an augmented reality environment [27]. Posters, especially e-posters, could also be implemented in online or blended learning environments [28].

CONCLUSION

In conclusion, integrating project-based learning, specifically through designing and presenting e-Posters, offers a valuable approach to teaching and learning in the Basic Physics course for pre-service science teachers. The results highlight the importance of multiple assessment sources, instructor guidance, and recognition in fostering student engagement, skills development, and conceptual understanding. By leveraging innovative pedagogical strategies and technology-enhanced tools, educators can effectively prepare pre-service science teachers for future teaching practice and promote meaningful learning experiences in physics education.

Future research endeavours in project-based learning for pre-service science teachers in physics education could explore longitudinal studies to assess the sustained impact of project-based learning on the retention of physics concepts and teaching practices over time. Additionally, comparative analyses could be conducted to evaluate the effectiveness of project-based learning against traditional instructional approaches. At the same time, investigations into integrating emerging technologies like virtual and augmented reality could offer innovative strategies for enhancing student engagement and learning outcomes. Furthermore, research focusing on integrating project-based learning experiences into teacher preparation programs may shed light on effective methods for improving teacher readiness and effectiveness in the classroom.

All e-posters can be accessed through the link below:
https://drive.google.com/drive/folders/1amjjJTaHoqdlWxqH2VHEFFpSYKf97TD6?usp=sharing

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