Hybrid Ethno-Project Based Learning Integrated With Virtual Assistive Technology to Enhance Students' Critical Thinking in Fundamental Physics Course

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Abstract **– The study explores the implementation of a novel pedagogical approach, hybrid ethnoscience-project based learning (E-PjBL) integrated with virtual assistive technology (VAT), to cultivate CT skills among students in a basic physics course. The E-PjBL framework integrates relevant cultural contexts and real-world projects into the physics curriculum. The presence of VAT provides a visual learning experience regarding ethnoscience contexts while also serving as a means to explain physics concepts at a high level of abstraction. The findings of our experiments reveal that students exposed to this hybrid approach show significant improvement in their CT skills, such as analysis, inference, evaluation, and decision-making. This research contributes to the growing knowledge of effective pedagogies that support the development of CT skills in the context of physics.**

Keywords **– Ethnoscience, project-based learning, virtual assistive technology, critical thinking skills.**

DOI: 10.18421/TEM124-11
https://doi.org/10.18421/TEM124-11

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Received: 12 June 2023.
Revised: 13 September 2023.
Accepted: 06 October 2023.
Published: 27 November 2023.

1. Introduction

Acquisition of critical thinking (CT) skills in learners is crucial in order to create a pool of talented learners in continuous education programs [1]. In modern higher education systems, critical thinking is recognized as a competency that supports students' professional abilities in the future [2]. For this reason, the curriculum in developed countries considers CT as a core attribute of graduates in higher education systems [3]. Consequently, every learning effort should be oriented towards improving students' CT performance [4]. However, this is not an easy task, given that CT training remains a challenge [5], primarily because the training mechanisms lack adequate intervention in the learning model [6]. As a result, students' CT performance falls short of expectations.

Several previous studies have found unsatisfactory results regarding students' CT performance. For example, an essay study conducted with 38 students in Sweden revealed their poor analytical skills [7]. Learning experiences that do not emphasize CT with effective pedagogy have an effect on the low achievement of CT among learners in China [8]. Similarly concerning results have been observed in developing countries, where learners' CT skills are underdeveloped in the process of learning [9]. Moreover, in physics education, students often encounter abstract physics concepts, which further hinder their learning and the development of their CT skills [10]. It is recommended that serious and planned efforts be made to address the issues related to the students' low CT skills [9].

Currently, the emphasis on CT skills for sustainable education development is directed towards project-based learning (PjBL) processes [11], with an emphasis on context-based problems rooted in the cultural entities in which students grow and develop [12].

Knowledge of local wisdom values (ethnoscience) provides an advantage in contextualizing authentic problems that support meaningful learning [1]. Indeed, PjBL is more engaging than traditional teaching methods [13] and can enhance students' learning involvement [14]. Previous studies have shown that PjBL alone is not effective in developing critical thinking skills [15]. The solution is to combine PjBL with a learning system utilizing adequate digital technology [16]. However, to our best knowledge, this has not been realized, especially the hybridization of PjBL with advanced assistive technology while preserving the characteristics of the learning process, particularly in reaching abstract physics subjects. Ultimately, to this day, the issues related to students' critical thinking performance remain a priority problem that needs to be resolved.

2. Hybrid E-PjBL Integrated with VAT

Improving the CT skills achievement of prospective science teachers is attempted through the intervention of innovative pedagogical model infrastructure. Its supportive capacity involves three aspects. First, emphasizing a well-rounded educational approach that fosters the development of holistic cognitive patterns through the incorporation of indigenous knowledge or local wisdom [17].

This can be characterized by ethnoscientific learning [18]. Second, modernizing the learning process that allows students to manipulate their cognitive skills through exploration [19]. The PjBL is a potential approach that helps learners develop and manipulate their cognitive skills [20]. Third, creating a digital model infrastructure in learning by developing assistive virtual technology. This is to create a motivating digital learning environment [21], [22] that has the potential to train students' thinking skills [23].

PjBL is characterized by the concept of ethnoscience, becoming an innovative model in learning, namely Ethno-PjBL (E-PjBL). The combination of E-PjBL is integrated with assistive virtual technology as a digital pedagogical infrastructure prepared to fulfill the functions of E-PjBL in hybrid learning. The presence of assistive virtual technology can provide a visual learning experience of ethnoscience contexts while also serving as a means to explain scientific concepts at a high level of abstraction [23], [24]. Hybrid E-PjBL integrated with assistive virtual technology developed as an innovative pedagogical model infrastructure can be a solution to enhance the CT skills of students in physics courses. The intervention of learning with hybrid E-PjBL integrated with assistive virtual technology is presented in Figure 1.

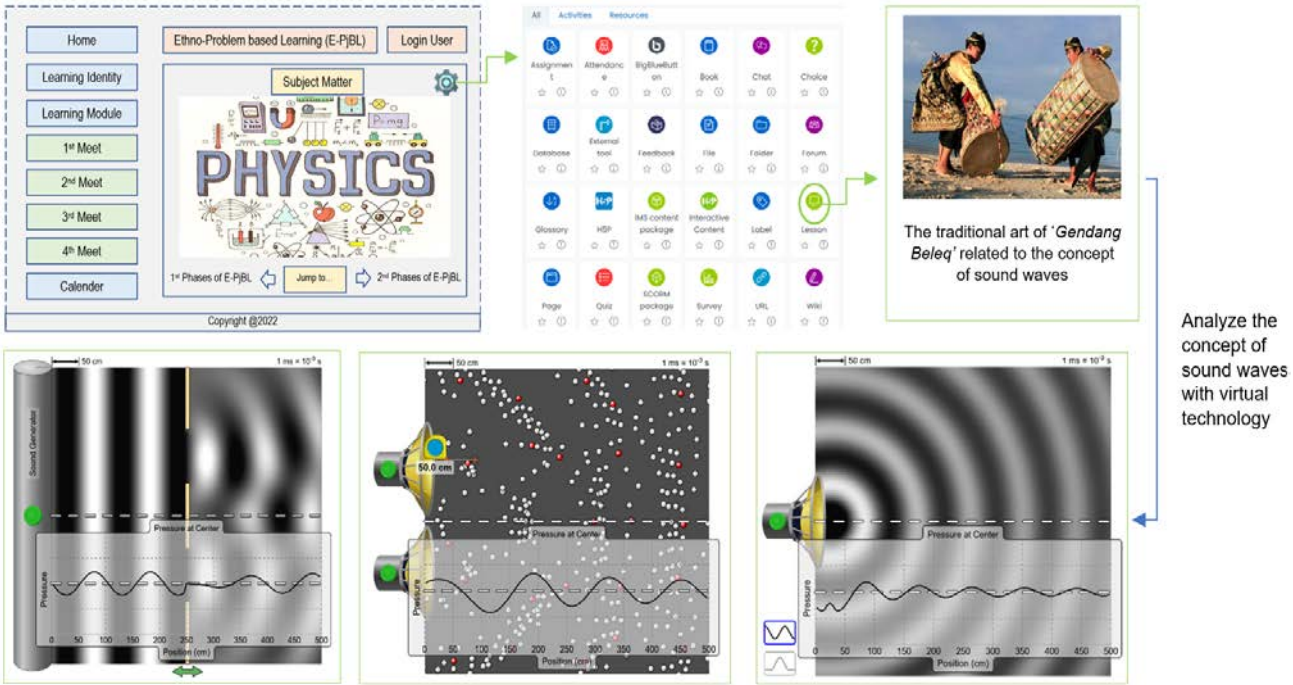

Figure 1. Hybrid E-PjBL integrated with virtual assistive technology

Previous empirical studies have shown that ethnoscience, PjBL (Project-based Learning), and virtual assistive technology have been investigated in separate domains.

However, their combination has not been examined as an innovative pedagogical infrastructure used to train students' critical thinking.

Ethnoscience, in its evolving terminology, involves the integration of the values of local cultural wisdom with scientific principles [18]. Ethnoscience represents a knowledge framework that embraces interpretations of the natural world, possesses practical utility, and finds application in predictive aspects within the realm of education [25]. Prior research has indicated that integrating ethnoscience into learning has a positive effect on enhancing learners' levels of scientific literacy [26], and influences their logical and CT skills in learning [17], [27].

Practical teaching with an ethnoscience context can promote thinking skills when combined with a core model of learning that leads to the process of exploration [17]. Through exploration, students' cognitive skills can develop as potential parameters for the development of critical thinking [19], [28], [29]. One potential learning approach that helps students develop and manipulate their cognitive skills is PjBL [20]. PjBL has a positive effect towards the motivation, collaborative performance, and the development of real-life competencies of the students [30], [31], [32]. The investigative process in PjBL that utilizes technology can enhance students' creative thinking processes [33], improve academic achievement [34], increase student engagement in learning [35], and make learning more engaging [36].

The relevance of embracing novel approaches to science education is on the rise due to the growing influence of technology, leading to virtual systems [37]. Its utilization is a current trend in modern learning [38]. The utilization of virtual technology in learning physics has an impact on the mastery of concepts and preferences for better theories, as well as an improvement in thinking skills [39], [40]. Virtual technology can visualize abstract physics concepts, expanding students' thinking scope and leading to enhanced analytical and critical abilities [23]. Students have also shown a high acceptance of its application [41], and it has been proven to have a positive impact on knowledge acquisition, skills, and attitudes [42]. Its advantages are evident as virtual technology helps address learning issues related to accessibility [43]. Virtual technology allows for the creation of environments that empower students to customize scientific experimental variables to suit their requirements [44].

3. Experimental

The experimental method (one group pre-posttest design) was used to examine the effectiveness of hybrid E-PjBL integrated with virtual assistive technology in enhancing students' CT skills.

The experiments were conducted in a fundamental physics course involving 23 students who were studying in the physics education department at Mataram University - Indonesia.

Pretest and posttest measurements of students' CT skills were taken before and after the intervention of the learning process using hybrid E-PjBL integrated with virtual assistive technology. The CT skill indicators measured are analysis (ANA), inference (INF), evaluation (EVA), and decision making (DM).

The data collection instrument for the pre- and post-tests consisted of eight essay items. They have been tested for their psychometric properties and can be used in this study. The lowest score for each CT indicator is -1 and the highest is +3. The data on critical thinking based on the aspect (indicator) parameters were analyzed descriptively using statistical analysis of variance (ANOVA). The average scores of students' CT in the pre- and post-tests for each indicator were grouped into various criteria, ranging from very critical to not critical [45].

The effectiveness of hybrid E-PjBL integrated with virtual assistive technology was measured in three aspects. First, there was an increase in the n-gain score from pre-test to post-test, following Hake's rule [46]. Second, the post-test scores met the minimum criteria for being critical. Finally, there was a variance in the scores of CT skills between the pre-test and post-tests. To support the data analysis process, an adequate analysis tool, JASP-0.17.2 was used.

4. Results and Discussion

Table 1 displays the outcomes of a descriptive examination of students' CT skills between pre- and posttests before and after the intervention of the learning process with hybrid E-PjBL integrated with assistive virtual technology. Raincloud plots of students' CT performance in the pre- and post-tests are presented in Figure 2.

Table 1. Descriptive analysis results of students' CT skills per indicator

Indi-cator	Group	N	Mean	SD	SE	Ceriteria
ANA	Post-test	23	2.783	0.295	0.061	Very critical
	Pre-test	23	0.000	0.564	0.118	Less critical
INF	Post-test	23	2.717	0.422	0.088	Very critical
	Pre-test	23	0.283	0.496	0.103	Less critical
EVA	Post-test	23	2.652	0.351	0.073	Very critical
	Pre-test	23	0.152	0.532	0.111	Less critical
DM	Post-test	23	2.761	0.333	0.069	Very critical
	Pre-test	23	0.152	0.463	0.097	Less critical

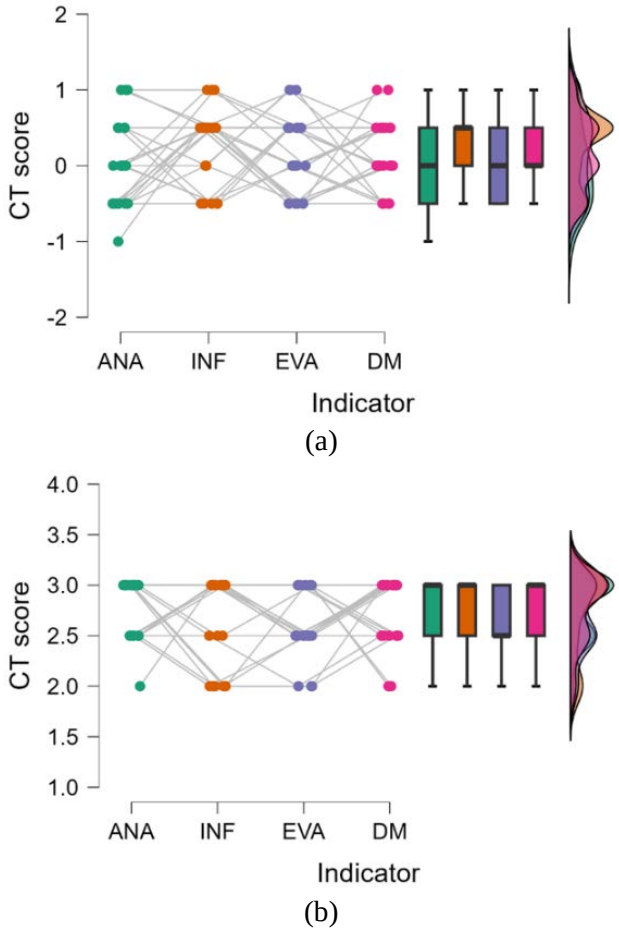

Figure 2. Raincloud plots of students' CT results on: (a) pre-test, and (b) post-test

For all indicators of CT skills, the pretest results were categorized as less critical. However, in the posttest, the CT skill results of the students improved to the level of very critical for all CT indicators. The calculation of n-gain for each CT indicator indicates that they fall under the high criteria, with scores of 0.92 for analysis, 0.90 for inference, 0.87 for evaluation, and 0.91 for decision-making. The distribution of CT scores is presented in raincloud plots (Figure 3). Based on the data distribution, it is evident that the mean scores for each CT indicator in the pre-test fell within the range of scores categorized as very critical, whereas in the posttest, they were very critical. Furthermore, Table 2 displays the results of the ANOVA comparing CT indicators across different groups (pre- and posttest).

Table 2. The ANOVA results between CT indicators and groups (pre- and post-test)

Cases	SS	df	MS	F	p	η^2
CT	0.352	3	0.117	0.628	0.598	0.001
CT ✻ Groups	0.798	3	0.266	1.423	0.239	0.002
Residuals	24.663	132	0.187	-	-	-
Groups	306.55	1	306.55	1395.88	< .001	0.896
Residuals	9.663	44	0.220	-	-	-

The findings presented in Table 2 indicate that there is no significant difference in CT skills among the groups (CT indicator vs. Groups) ($F = 1.423$, $p = 0.239$, $\eta^2 = 0.002$). However, a significant difference was found in the average of CT skill scores between the pre-test and post-test ($F = 1395.880$, $p < .001$, $\eta^2 = 0.896$). This finding confirms the descriptive analysis results that students' CT skills for all indicators have improved from less critical to very critical. This means that the integrated hybrid E-PjBL with assistive virtual technology has been proven effective in enhancing students' CT skills in the fundamental physics course.

The enhancement of CT skills among students in the fundamental physics course is due to the hybrid E-PjBL factor supported by the presence of assistive virtual technology. The values taught effectively in PjBL have a positive impact on students' problem-solving skills [47], [48] and thinking competency in the context of the studied material [11], [49]. Students' thinking competency is sharpened through contextual and meaningful learning experiences, such as in ethnoscience learning [50].

Enhancing the meaningfulness of learning through hybrid E-PjBL, the presence of assistive virtual technology actually supports the success of learning in training CT skills among students. The results of this study align with prior research that emphasize learning approaches involving exploration processes using assistive virtual technology, which can sharpen students' CT skills in physics courses [23]. Students' reasoning skills develop when they utilize assistive virtual technology to visualize abstract physics materials [51]. The combination of learning in the context of ethnosciences and emphasizing exploratory processes (such as PjBL) provides opportunities for the cultivation of learners' CT skills [1]. Finally, the findings of this study provide confidence that the integrated assistive virtual technology in hybrid E-PjBL has been able to enhance students' CT skills in fundamental physics courses.

5. Conclusion

A study has implemented the integrated hybrid E-PjBL with virtual assistive technology to enhance students' CT skills in fundamental physics courses. Through experiments, the study's results indicate that the integrated hybrid E-PjBL with virtual assistive technology has been effective in improving students' CT skills. The students' CT performance increased from "less critical" to "very critical" after implementing the learning approach, as evidenced by acquiring high scores on the n-gain criteria.

The results of CT also showed a significant difference from the pretest and posttest, indicating that the integrated hybrid E-PjBL with virtual assistive technology is effective in enhancing students' CT skills. Based on the current study's findings, it is appropriate to widely utilize this learning design, particularly in teaching physics concepts more effectively.

Acknowledgements

This study is a domestic collaborative research project fully funded by the government of the Republic of Indonesia through the Ministry of Education, Culture, Research, and Technology (contract number: 134/E5/PG.02.00.PL/2023, sub-contract number: 3189/UN18.L1/PP/2023). The researchers would like to express their utmost gratitude to all parties involved in this research.

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