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Dynamic blend of ethnoscience and inquiry in a digital learning platform (e-learning) for empowering future science educators' critical thinking

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Abstract

Inquiry-based learning overcomes the gap between the acquisition of knowledge through discovery though it is not always directly proportional to students' development of critical thinking (CT). Knowledge about the real-world contexts in which children will learn is the first step in cultivating CT in science learning. Science inquiry is most relevant when it is linked to the cultural context and local wisdom in which students are growing and developing. On one hand, the current focus of learning is on digital systems which can also provide opportunities to enhance CT. The current study aims to implement a blend of inquiry-based learning and Ethnoscience on a digital learning platform (e-learning) and assess its effect on the pre-service science teachers' (PSTs) CT abilities. The study is conducted using an experimental method involving PSTs as participants. Several valid test instruments are employed to measure CT skills and the results are analyzed. According to the study's findings, there have been notable advancements in CT due to the digital learning platform's dynamic fusion of Ethnoscience and inquiry. This study demonstrates that the dynamic blend of Ethnoscience and inquiry in a digital learning platform can serve as a cutting-edge learning method for empowering CT particularly in future science teachers.

Keywords: Critical thinking, Digital learning platform, Dynamic blend, Ethnoscience, Future science educators, Inquiry learning.

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Contents

Contribution of this paper to the literature
This study presents an innovative approach that successfully enables critical thinking in the context of science education by combining traditional inquiry-based learning with Ethnoscience contexts. The findings underscore the potential of this innovative blend as an advanced pedagogical method to foster critical thinking particularly in the preparation of future science teachers.

1. Introduction

Digital technology growth, internet usage and the expanding trend of online learning have revolutionized education replacing traditional face-to-face instruction with distance instruction through electronic learning platforms (Asy'ari & Da Rosa, 2022). Palvia et al. (2018) believe that by 2025, e-learning will be extensively used in all forms of education and learning globally. Educational stakeholders will be faced with the challenging task of developing the necessary modern pedagogical framework through digital technologies (Schumann et al., 2019). On the other hand, developing pre-service teachers' critical thinking skills is essential if we want them to meet the global educational demands of the twenty-first century (Huang & Sang, 2023).

Critical thinking (CT) has become increasingly significant in higher education in the present era. CT is necessary for learners' future professional abilities and overall learning experience (Erikson & Erikson, 2019). This problem has attracted a lot of attention even in developed countries where universities have highlighted CT skills as essential graduation competencies (Prayogi & Yuanita, 2018). Consequently, CT is the ultimate objective of all instructional strategies and classroom activities (Phillips, 2023). Gilmanshina, Smirnov, Ibatova, and Berechikidze (2021) pointed out that the process of teaching critical thinking in academic contexts is still lacking. They emphasised that lecturers' abilities and participation in the training were inadequate. According to Lee, Wang, and Lim (2021), the significance of critical thinking for university students is acknowledged but innovative instructional techniques continue to be a contentious issue. Prior research has revealed unsatisfactory results with regard to the critical thinking (CT) abilities of preservice science teachers (PSTs). For instance, Trostek (2020) conducted an essay-based study involving thirty-eight PSTs in Sweden and identified their inadequate analytical and reasoning skills. Similar findings were reported by Ma and Luo (2021) who found that prospective senior scholars at five Chinese universities had insufficient CT performance due to limited opportunities for CT-focused learning activities and inadequate support. Fitriani, Asy'ari, Zubaidah, and Mahanal (2019) also observed limited development of CT skills among PSTs and emphasized the need for effective interventions. Despite some educational institutions prioritizing academic success over CT, multiple studies indicate a positive relationship between students' critical thinking performance and their learning outcomes (Almulla, 2023; Ghanizadeh, 2017; Kleemola, Hyytinen, & Toom, 2022; Siburian, Corebima, & Saptasari, 2019; Suhirman & Prayogi, 2023) thus highlighting the importance of CT achievement for student success. Universities must apply modern teaching strategies such as inquiry-based learning to develop CT abilities in PSTs(Verawati, Hikmawati, Prayogi, & Bilad, 2021). If creative teaching is to be effective in improving students' CT skills, it must be multidimensional (Dekker, 2020). Multiplicity in the context of education refers to a dynamic combination of knowledge ideals, technology and cultural entities (Prayogi, Ahzan, Indriaturrahmi, & Rokhmat, 2022). The incorporation of local wisdom values is of utmost importance in the learning process (Myllykoski-Laine, Postareff, Murtonen, & Vilppu, 2023). This integration fosters a holistic perspective and facilitates the assimilation of both national and local wisdom. Indigenous knowledge is widely regarded as Ethnoscience and has a great deal of value in the field of science education Sudarmin et al. (2023). Universities can promote critical thinking where students are able to think critically, holistically and with an appreciation for their cultural heritage by implementing these strategies.

Arends (2012) points out that the basis of critical thinking teaching is inquiry since it teaches people how to think. Teaching Ethnoscience through exploration and inquiry possesses significant potential to enhance students' CT abilities (Prayogi et al., 2022). The dynamic blend of traditional wisdom in the knowledge system (Ethnoscience) and inquiry learning on a digital learning platform (e-learning) can provide students with a learning experience that supports their critical thinking abilities. This mode is considered innovative learning for several reasons. Firstly, interactive and innovative digital learning is necessary to facilitate interactivity in learning and achieve critical thinking objectives. Secondly, Ethnoscience is a vital component of contemporary science education especially in the context of promoting local cultural values and developing potential-based learning that boosts national competitiveness and enhances students' critical thinking. Finally, ethno-inquiry can serve as a learning that addresses science learning requirements by prioritizing the knowledge acquisition process and fostering critical thinking skills through contextual problem exploration activities.

1.1. Research Questions

The main objective of the current study is to implement ethno-inquiry learning on a digital platform (e-learning) and assess its effect on the CT abilities of PSTs. The research question is as follows:

- How does the integration of ethno-inquiry into digital learning platforms (e-learning) develop CT abilities among PSTs?

2. Literature Review

2.1. Critical Thinking

John Dewey, a well-known psychologist has been a supporter of critical thinking (CT) for a long time. He believes that CT is synonymous with reflective thinking which involves actively considering, persistently and thoroughly, knowledge in terms of reasoning (Dewey, 1910). On the other hand, passive thinking happens when students take ideas and information from others for granted which makes it more difficult for them to participate in active learning. Facione (2020) provides a detailed explanation of CT which involves interpretation, explanation, analysis and self-regulation learning activities. In addition, CT requires students to perform tasks such as evaluation, inference and decision- making (Ennis, 2011). Ennis (2011) defines CT as reasoning and reflection that focus on decision- making. In a similar perspective, Elder and Paul (2012) define CT as a way of reasoning about issues and highlight that students can enhance their thinking by understanding the inherent structures of the mind and applying intellectual standards.

Examining the literature shows that many professionals consider CT to be a crucial skill. Scholars have identified three approaches to CT: educational, cognitive psychological and philosophical. The goal of the teaching strategy is to raise students' thinking to higher levels of HOTS (Higher-Order Thinking Skills). The cognitive-psychological perspective emphasizes the observable actions of an individual engaged in critical learning and the essential competencies they should acquire. Meanwhile, the philosophical standpoint focuses on the attributes and qualities associated with critical thinking. In this study, the researchers follow the criteria of CT provided by Ennis (2011) and use four fundamental markers of CT. They are the abilities of analysis, inference, evaluation and making decisions. Extensive discussions regarding these markers have been conducted in prior research demonstrating the integration of philosophical, psychological and educational viewpoints on CT. Additionally, these markers align with the demands for critical thinking in higher education further emphasizing their relevance.

2.2. Inquiry Learning

The diversity of teaching and research projects related to scientific inquiry indicates the growing popularity of inquiry-based learning in the field of science education (Pedaste et al., 2015). This pedagogical method traces back to the early 1900s when John Dewey placed a strong emphasis on inquiry-based learning (Tillmann, Albrecht, & Wunderlich, 2017). Some scholars state that the concept of inquiry derives from the Atkin-Karplus learning cycle which was introduced in 1962 and outlines the steps involved in inquiry-based activities (Hussain, Azeem, & Shakoor, 2011). Sund (1973) argues that inquiry learning is a pedagogical approach that encourages learners to develop, apply and understand new ideas through systematic questioning, experimentation and hypothesis testing. In this approach, students take on the role of professional scientists and construct their knowledge through the discovery of causal relationships (Ekayanti, Prayogi, & Gummah, 2022; Keselman, 2003). The inquiry-based learning process begins with hypothesis formulation and proceeds with experimental testing (Pedaste et al., 2015). Previous findings indicate that inquiry can produce better learning outcomes when compared to direct teaching methods (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Prayogi, Ardi, El Yazidi, Tseng, & Mustofa, 2023) and is more effective than traditional teaching in terms of training students to think critically (Kirk, Tytler, & White, 2023). Arends (2012) characterizes review as a model of learning that trains students how to think. The learning mission of inquiry emphasizes both content and processes. The content component aims to lead learners towards novel insights through investigative activities while the process component helps students learn about inquiry activities particularly scientific inquiry and cultivate a positive attitude towards them. Various terms such as scientific inquiry, inquiry teaching, structured inquiry, open inquiry and guided inquiry (Buck, Bretz, & Towns, 2008) have been employed by experts to describe inquiry-based learning. Nonetheless, the main focus of these methods is on identifying the problem first, then developing a hypothesis and conducting experiments to prove it. This involves various tasks such as collecting and analyzing the data and drawing conclusions (Minner, Levy, & Century, 2010).

2.3. Ethnoscience

The term Ethnoscience was coined in the 1960s and is commonly used to describe the study of the conceptual frameworks used by indigenous populations to arrange their understanding of their surroundings (Rist & Dahdouh-Guebas, 2006). The term Ethnoscience is derived from the Greek word "Ethnos" meaning nation and the Latin word "Scientia" meaning knowledge referring to the knowledge held by ethnic or social groups. According to Sturtevant (1964), Ethnoscience is a knowledge and cognitive system specific to a particular culture that emphasis on knowledge unique to a community also referred to as local wisdom. The objective of Ethnoscience is to recognize important physical phenomena in a community or culture and arrange them within their understanding which is also known as indigenous science or native knowledge. Ethnoscience is a knowledge system that belongs to traditional or native cultures encompassing environmental factors and the interactions between humans and nature (Zidny & Eilks, 2022). It is also referred to by other terms such as "traditional ecological knowledge" or "indigenous science" (Botha, 2012; Zidny, Sjöström, & Eilks, 2020).

2.4. Blend of Ethnoscience Inquiry into Digital Learning

The blend of Ethnoscience and inquiry appears to be a promising approach to integrating cultural values and local wisdom with inquiry activities in teaching science. Learners can investigate their local environment and culture and build CT through exploration activities by integrating principles from Ethnoscience into scientific inquiry activities (Verawati, Harjono, Wahyudi, & Gummah, 2022). The process of developing thinking skills in the context of a blend of inquiry learning and Ethnoscience gives students the ability to consider scientific phenomena and cultural traditions, pinpoint specific issues and find solutions based on other analytical techniques and scientific principles (Kurniawan & Syafriani, 2021). Students can improve their critical thinking and scientific thinking skills as well as obtain a better understanding of the local culture and environment (Zulirfan, Yennita, Maaruf, & Sahal, 2023). The ethno-inquiry should be adapted to meet the local context of the learners and their cultural values. The learning is designed to promote active learning and student-centered approaches to teaching science where students are encouraged to ask questions, investigate and solve problems. Additionally, it is crucial to provide adequate support and guidance for students as they engage in learning activities to ensure that they are able to develop their CT skills effectively. Research conducted in the past has indicated that teaching Ethnoscience has a positive effect on learners' attitudes towards science (Fasasi, 2017).

The ethno-inquiry learning consists of five learning phases namely: ethno-orientation, ethno-reflection, ethno-authentic problem, ethno-problem solving and ethno-explanation (Prayogi et al., 2022). They are taught on digital platforms (e-learning) (see https://ethno-inquiry.id/). This is consistent with the increasing use of digital technologies, interest in online resources and popularity of virtual learning as a substitute for traditional face-to-face instruction. An effective online learning model is required to enhance the development of critical thinking abilities through interactive and inventive digital learning. Previous research indicates that e-learning can enhance students' critical thinking abilities (Chen & Wu, 2023) as it can provide an active and collaborative learning environment that fosters student engagement and critical thinking skills (Ebadi & Rahimi, 2018).

3. Methodology

3.1. Design of the Study

The study used a randomized pre- and post- tests control design which is a type of true experimental study (Fraenkel, Wallen, & Hyun, 2012).

$$\text{Experimental group} \quad Rd \;\; O_1 \;\; X \;\; O_2$$

$$\text{Control group} \quad Rd \;\; O_1 \;\; C \;\; O_2$$

The study involved the creation of both experimental (X) and control (C) groups with measurements pre-test (O_1) and post-test (O_2) at two different times. Randomization (Rd) techniques were employed to create the two groups. The experimental group (X) received a learning treatment using a blend of Ethnoscience and inquiry learning on a digital platform (e-learning) whereas the control group (C) was exposed to regular instruction that followed a more traditional teaching approach (expository).

3.2. Participants

The research sample consisted of 55 science teacher candidates (PST), they were divided into experimental (n=27) and control (n=28) groups. The age of PST ranged from 19 to 20 years and the distribution of males and females was relatively even. They are PSTs who are currently studying at the Mandalika Education University (UNDIKMA) in Indonesia. The research was conducted in compliance with ethical guidelines and study approval issued by the Institution of Research and Community Service (reference number 105/2023).

3.3. Procedures

In this study, the research methodology was conducted according to a predetermined design. PSTs were randomly selected to form both experimental and control groups. A pre-test was administered using an appropriate tool to evaluate their critical thinking abilities. A post-test assessment of critical thinking ability was administered to both groups following the completion of the learning process. Measures were taken such as forming balanced sample groups, conducting the pre- and post-tests simultaneously, scheduling learning processes simultaneously, using similar materials and ensuring that tutors in both groups had comparable experience and knowledge to minimize threats to internal and external validity. Finally, the results of the pre- and post- tests were analyzed and interpreted adequately based on the research objectives.

3.4. Research Instruments

In this study, various learning tools were used in the classroom, namely lesson plans and scenarios, e-modules and worksheets as well as a CT ability test instrument. The CT skill test instrument contained eight essay questions that assessed critical thinking skills in the areas of analyzing (ANA), inferencing (INF), evaluating (EVA) and decision-making (DM). Two competent practitioners and lecturers in science education validated the learning aids to assure their validity and reliability. They evaluated the content and construct validity. The reliability of the tools was evaluated through percentage agreement. The results of the validation show that learning tools are valid and reliable and form the basis on which learning tools can be employed to support the study. The Ennis-Weir critical thinking essay test which scored the test instrument using five scales (-1, 0, +1, +2, and +3) (Ennis & Weir, 1985) was used to score the test instrument with each critical thinking indicator containing two essay test items resulting in a total of eight items for the test instrument.

3.5. Data Analysis

A descriptive analysis of CT ability scores provides a summary of the tendency, dispersion and shape of the CT data for each group. This analysis helps to describe and understand the distribution of CT ability scores among participants. Statistical analysis of CT ability scores can help determine whether there is a significant difference in CT abilities between the experimental and control groups.

This study measures the CT ability of PSTs in two parameters namely CT ability based on indicator score (CTi) and CT ability based on group accumulated score (CTa). The CTi and CTa criteria are classified into five categories ranging from very critical to not critical. The acceptable range of scores for each CT ability criterion is as follows: very critical ($CT > Xi + 1.8Sdi$), critical ($Xi + 0.6Sdi < CT \leq Xi + 1.8Sdi$), quite critical ($Xi - 0.6Sdi < CT \leq Xi + 0.6Sdi$), less critical ($Xi - 1.8Sdi < CT \leq Xi - 0.6Sdi$) and not critical ($CT \leq Xi - 1.8Sdi$). Here, Xi refers to the ideal mean [½ (max. score + min. score)] and Sdi refers to the ideal standard deviation [1/6 (max. score – min. score)]. The criteria for CT abilities are presented in Table 1.

Table 1. The criteria for CT abilities and interval scores of CTi and CTa.

CT ability criteria	CTi score intervals	CTa score intervals
Very critical	$CTi > 2.20$	$CTa > 17.6$
Critical	$1.40 < CTi \leq 2.20$	$11.2 < CTa \leq 17.6$
Quite critical	$0.60 < CTi \leq 1.40$	$4.8 < CTa \leq 11.2$
Less critical	$-0.20 < CTi \leq 0.60$	$-1.6 < CTa \leq 4.8$
Not critical	$CTi \leq -0.20$	$CTa \leq -1.6$

In this study, normality gain (n-gain) analysis was used to determine the improvement in CT abilities between the pre-and post-tests of each group. The N-gain score is calculated using Hake's formula: <g> = (post-test score pre-test score) / (maximum possible score – pre-test score) (Hake, 1999). The n-gain score ranges from 0 to +1, and the interpretations for the n-gain scores are < 0.30 (low); 0.30 ≤ g ≤ 0.70 (moderate); and > 0.70 (high). Furthermore, the Analysis of Variance (ANOVA) was employed to analyze the difference in CT scores between the pre- and post-tests in each treatment group. Their significance level was set at 0.05. This test helps determine whether the observed differences in CT scores are statistically significant or vice versa.

4. Findings

Studies have been carried out by implementing ethno-inquiry on digital learning platforms (e-learning) and assessing their effect on the CT abilities of PSTs. The study has measured the CT ability of PSTs in two parameters, namely CT ability based on indicator score (CTi) and CT ability based on group accumulated score (CTa).

4.1. The Analysis Results of CT Ability Based on Indicator Score (CTi)

The CT ability of PSTs based on indicator score (CTi) is presented in Tables 2 and 3. The data distribution of CT scores in the experimental and control groups is presented in Figures 1 and 2 respectively. The CTi abilities measured are aspects of analysis, inferences, evaluation and decision-making. The pre-and post-tests and n-gain scores were calculated for each group based on the four CT indicators.

Table 2. The descriptive analysis results of the CTi for the experimental group (N = 27).

CT indicator	Pre-test			Post-test			N-gain	Criteria
	Min.	Max.	Mean (±SD)	Min.	Max.	Mean (±SD)		
Analysis	-1.00	1.00	0.037 (±0.553)	2.00	3.00	2.796 (±0.286)	0.93	High
Inference	-1.00	1.00	0.185 (±0.557)	2.00	3.00	2.703 (±0.422)	0.89	High
Evaluation	-0.50	1.00	0.166 (±0.500)	2.00	3.00	2.629 (±0.356)	0.87	High
Dec.-making	-1.00	1.00	0.148 (±0.515)	2.00	3.00	2.741 (±0.321)	0.91	High

Note: SD = Standard deviation, n-gain = Normality gain.

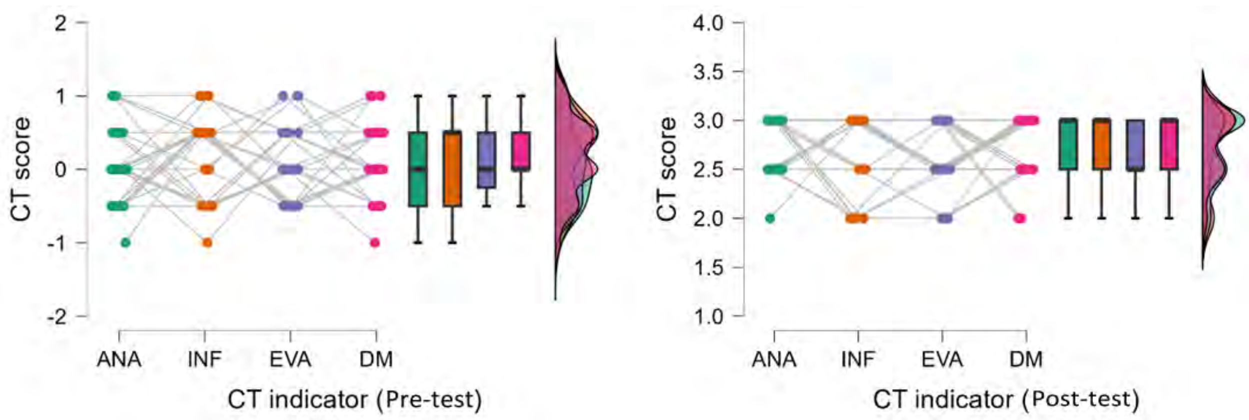

Figure 1. The data distribution of CT scores (pre- and post-tests) in the experimental group.

The results in Table 2 and Figure 1 indicate that the average CTi scores for the four measured indicators increased from the pre-test to the post-test in the experimental group (N = 27). For the pre-test, the CTi score range decreased within the criteria of being less critical (-0.20 < CTi ≤ 0.60). The highest average CTi scores for the pre-test were in the inference indicator (mean = 0.185 ± 0.557) followed by evaluation (mean = 0.166 ± 0.500), decision -making (mean = 0.148 ± 0.515) and analysis (mean = 0.037 ± 0.553). Meanwhile, the highest post-test scores were observed in the analysis indicator (M = 2.796 ± 0.286) followed by decision-making (M = 2.741 ± 0.321), inference (M = 2.703) and evaluation (M = 2.629 ± 0.356). For the post-test, the CTi score range decreased within the criteria of being very critical (CTi > 2.20).

Table 3. The descriptive analysis results of the CTi for control group (N = 28).

CT indicator	Pre-test			Post-test			N-gain	Criteria
	Min.	Max.	Mean (±SD)	Min.	Max.	Mean (±SD)		
Analysis	-0.50	1.00	0.285 (±0.417)	0.00	2.00	0.857 (±0.506)	0.21	Low
Inference	-0.50	1.00	0.267 (±0.480)	0.00	1.00	0.571 (±0.295)	0.09	Low
Evaluation	-0.50	1.00	0.321 (±0.547)	0.00	1.50	0.946 (±0.368)	0.23	Low
Dec.-making	-0.50	1.00	0.250 (±0.518)	0.00	1.50	0.785 (±0.370)	0.19	Low

Note: SD = Standard deviation, n-gain = Normality gain.

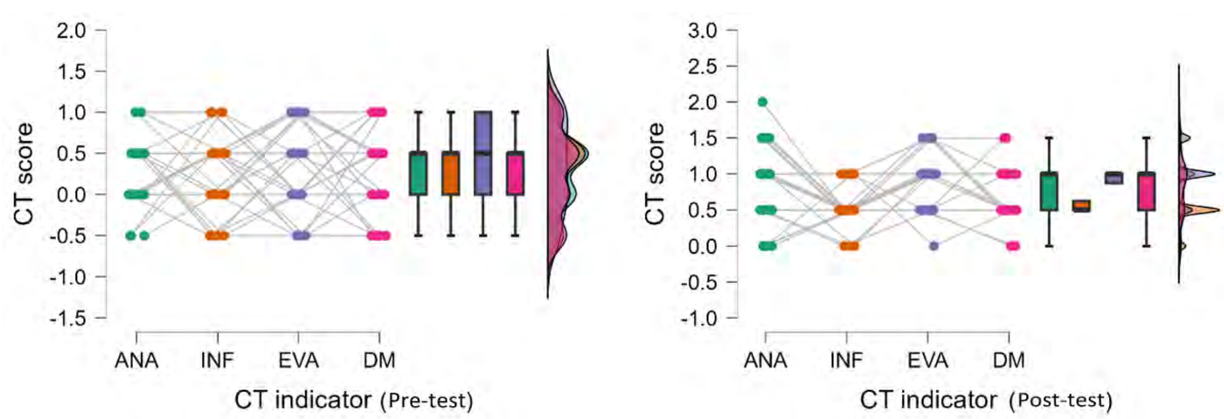

Figure 2. The data distribution of CT scores (pre- and post-tests) in the control group.

The descriptive analysis results of the CTi for the control group (N = 28) (see Table 3 and Figure 2) indicate that their highest average pre-test score is in the evaluation indicator (mean = 0.321 ± 0.547) followed by analysis, inference and decision-making. The pre-test scores of CTi for all indicators fall within the less critical criteria (– 0.20 < CTi ≤ 0.60). For the post-test, the highest CTi score in the control group is in evaluation (mean = 0.946 ± 0.368) followed by analysis, decision-making and inference. The post-test CTi scores for the control group fall within the quite critical criteria (0.60 < CTi ≤ 1.40) except for the inference indicator which remains within the less critical criteria (mean = 0.571 ± 0.295).

The description of the results in Table 2 shows that the n-gain for all CT indicators in the experimental group falls within the high criteria (> 0.70) with scores ranging from 0.87 to 0.93. The highest n-gain score is observed for the analysis indicator followed by decision-making, inference and evaluation. On the other hand, the n-gain scores in the control group fall within the low criteria (< 0.30) for all CT indicators.

Furthermore, the differences in CTi scores between indicators in the two treatment groups (experimental and control) were statistically analyzed using an ANOVA test ($p < 0.05$). The test is based on the normality of the tested data groups where they obtained p-values > 0.05 indicating that all test data groups are normally distributed. The results of the ANOVA test are presented in Table 4.

Table 4. The ANOVA test results between CT indicators in two treatment groups (Experimental and control).

Indicator	Cases	SS	df	MS	F	p	η^2
Analysis	ANA (Pre-and post- tests)	76.242	1	76.242	343.284	< 0.001	0.507
	ANA ✻ Treat. groups	32.897	1	32.897	148.120	<0.001	0.219
	Residuals	11.771	53	0.222			
	Treat. Groups (Exp. – cont.)	19.640	1	19.640	104.466	< 0.001	0.130
	Residuals	9.964	53	0.188			
Inference	INF (Pre-and post- tests)	54.736	1	54.736	389.124	<0 .001	0.395
	INF ✻ Treat. Groups	33.718	1	33.718	239.703	< 0.001	0.243
	Residuals	7.455	53	0.141			
	Treat. Groups (Exp. – cont.)	28.871	1	28.871	110.509	<0 .001	0.208
	Residuals	13.847	53	0.261			
Evaluation	EVA (Pre-and post- tests)	65.535	1	65.535	369.989	<0.001	0.519
	EVA ✻ Treat. Groups	23.217	1	23.217	131.074	< 0.001	0.184
	Residuals	9.388	53	0.177			
	Treat. groups (Exp. – cont.)	16.056	1	16.056	69.833	< 0.001	0.127
	Residuals	12.185	53	0.230			
Decision.-making	DM (Pre-and post- tests)	67.259	1	67.259	375.572	< 0.001	0.479
	DM ✻ Treat. Groups	29.077	1	29.077	162.365	<0.001	0.207
	Residuals	9.491	53	0.179			
	Treat. groups (Exp. – cont.)	23.603	1	23.603	113.049	< 0.001	0.168
	Residuals	11.065	53	0.209			

Note: ✻ = Comparison of groups tested, SS = Sums of squares, MS = Mean squares, Df = Degrees of freedom, η^2 = Effect sizes.

The results in Table 4 indicate a significant difference among CT indicators between pre- and post-tests as well as between treatment groups (experimental and control). There were significant differences in CT scores for the analysis indicator between pre- and post-tests ($F = 343.284$, $p < .001$, $\eta^2 = 0.507$) and the treatment effect for the analysis indicator was significantly different ($F = 104.466$, $p < .001$, $\eta^2 = 0.130$). There were significant differences in CT scores for the inference indicator between pre- and post-tests ($F = 389.124$, $p < .001$, $\eta^2 = 0.395$) and the treatment effect for the inference indicator was significantly different ($F = 110.509$, $p < .001$, $\eta^2 = 0.208$). There were significant differences in CT scores for the evaluation indicator between pre- and post-tests ($F = 369.989$, $p < .001$, $\eta^2 = 0.519$) and the treatment effect for the evaluation indicator was significantly different ($F = 69.833$, $p < .001$, $\eta^2 = 0.127$). Lastly, for the decision-making indicator, their CT scores differed significantly between pre- and post-tests ($F = 375.572$, $p < .001$, $\eta^2 = 0.479$) and the treatment effect for the decision-making indicator was significantly different ($F = 113.049$, $p < .001$, $\eta^2 = 0.168$).

4.2. The Analysis Results of CT Ability Based on Group Accumulated Score (CTa)

The descriptive analysis results of CT are presented in Table 5 and Figure 3. The pre-test results of CT in both groups (experimental and control) fell under the less critical criteria. However, the results of the CT post-test differed between groups with the experimental group falling under the very critical criteria and the control group falling under the quite critical criteria.

Table 5. The descriptive analysis results of the CTa for the experimental and control groups.

Group	Average scores of CTa and criteria				N-gain	Criteria
	Pretest (±SD)	Criteria	Posttest (±SD)	Criteria		
Experimental, N = 27	1.074 (±2.234)	Less critical	21.740 (±1.430)	Very critical	0.89	High
Control, N = 28	2.250 (±1.936)	Less critical	6.321 (±1.866)	Quite critical	0.18	Low

Note: SD = Standard deviation, n-gain = Normality gain.

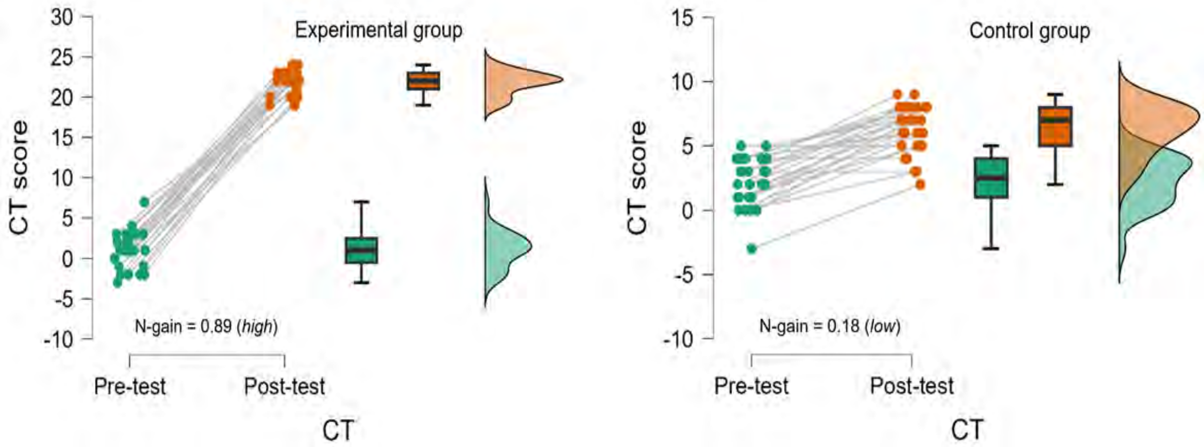

Figure 3. The data distribution of CTa scores (pre- and post-test) in the experimental and control group.

The average CTa scores in the pre-test for the experimental group were 1.074 (±2.234) and in the post-test, they increased to 21.740 (±1.430). Their n-gain scores fell into the high category with an n-gain value of 0.89 (> 0.70). In contrast, for the control group, their CTa score in the post-test was 6.321 (±1.866) and the n-gain score fell into the low criteria (< 0.30). Furthermore, the difference in CTa scores between the treatment groups (experimental and control) was analyzed using an ANOVA test ($p<0.05$). The test was based on the normality of the tested data groups where they acquired p-values > 0.05 indicating that all test data groups were normally distributed. The ANOVA results are presented in Table 6.

Table 6. The ANOVA test results between CT score (pre-and post-tests) in the experimental and control groups.

Cases	SS	Df	MS	F	P	η^2
CT (Pre-and post- tests)	4205.926	1	4205.926	1289.053	< 0.001	0.534
CT ✻ Treat. groups	1892.762	1	1892.762	580.103	<0.001	0.240
Residuals	172.929	53	3.263	-	-	-
Treat. groups (Exp. – Cont.)	1394.298	1	1394.298	359.660	< 0.001	0.177
Residuals	205.466	53	3.877	-	-	-

Note: ✻ = Comparison of groups tested, SS = Sums of squares, MS = Mean squares, Df = Degrees of freedom, η^2 = Effect sizes.

The results presented in Table 6 demonstrate a significant difference between the CT scores (pre- and post-tests) in the two treatment groups (experimental and control) ($F = 1289.053$, $p < 0.001$, $\eta^2 = 0.534$). The CT scores between the two treatment groups in the post-test also show a significant difference ($F = 359.660$, $p < 0.001$, $\eta^2 = 0.177$).

5. Discussion

The initial portrait reflects the critical thinking abilities of pre-service teachers (PSTs) before the ethno-inquiry learning intervention which was classified as less critical based on the CTi and CTa parameters. This was also observed in the control group taught through expository teaching. The low critical thinking abilities of PSTs were attributed to their learning experiences that did not train them in critical thinking. The insufficient training in critical thinking in the classroom teaching routines resulted in underdeveloped aspects of critical thinking such as analysis, inference, evaluation and decision-making for PSTs (Wahyudi, Verawati, Ayub, & Prayogi, 2019). Similar findings were also reported in previous studies (Evendi et al., 2022) where the initial critical thinking of students (pre-test) was inadequate before conducting critical thinking training.

In the current study, critical thinking training for PSTs was conducted by intervening with ethno-inquiry learning on a digital platform (e-learning). The results were highly successful in improving the critical thinking abilities of PSTs. The critical thinking abilities of PSTs reached a highly critical level showing a high acquisition score (n-gain) based on the CTi and CTa parameters. The CTi score experienced significant improvement for all indicators (analysis, inference, evaluation and decision-making). These findings simultaneously provide an answer to the challenges discussed in previous studies (Miri, David, & Uri, 2007; Qing, Jing, & Yan, 2010) that CT training with inquiry was hindered in aspects of inference and evaluation. In fact, inquiry-based education combined with an Ethnoscience context and delivered through a digital learning environment can improve PSTs' CT performance.

The combination of inquiry-based learning with ethnosciences on a digital learning platform makes it superior in the context of CT training compared to traditional teaching. It is even better compared to traditional inquiry-based learning (inquiry carried out in a physics laboratory without a digital platform) as previous studies (Prayogi & Yuanita, 2018) have found in CT training (based on n-gain parameters). The experimental results of Prayogi and Yuanita (2018) confirm the finding that the average increase in CT scores from PST (n-gain) in inquiry-based learning is moderately classified ($0.30 \leq g \leq 0.70$) while in our current experiment, we found an average n-gain in the high category. Inquiry helps students develop their process skills so they can experiment and investigate in order to enhance their critical thinking abilities, conceptual understanding and science learning objectives (Cairns, 2019; Kustadiyono, 2020). However, its implementation does not always directly contribute to the development of students' critical thinking (Uiterwijk-Luijk, Krüger, Zijlstra, & Volman, 2019).

A digital learning framework and integration with the Ethnoscience context are key components that make inquiry-based learning successful in current studies. The integration with ethnosciences makes inquiry-based learning more authentic (Verawati et al., 2022) and the combination of inquiry within the digital learning framework makes it more interactive and engaging making it suitable for distant learning (West, Hill, Abzhaparova, Cox, & Alexander, 2023). Ethnoscience and inquiry combined in a digital learning environment is an innovative method of learning that enhances CT more than traditional teaching methods. This has been demonstrated through statistical analysis showing significant differences in CT outcomes between PSTs in both learning approaches. It is evident that traditional teaching is inadequate for CT training purposes.

The reflection of cultural values and local wisdom as Ethnoscience is explored in inquiry experiments becomes a key factor in the success of CT training for PSTs. Students engage in self-reflection regarding the application of scientific norms within their cultural context and local knowledge by using Ethnoscience and inquiry-based learning approaches. This reflective practice holds significance as it enables students to develop an understanding of self-assessment throughout the learning process and their unique thinking perspectives (Choy, Yim, & Tan, 2017). It not only develops thinking abilities but also has a positive effect on more profound and significant learning (Griggs, Holden, Lawless, & Rae, 2018). The findings of this study are consistent with Colomer, Serra, Cañabate, and Bubnys (2020) findings that reflection practices can encourage reasoned action plans for making decisions. It is widely recognized that the ability to engage in reasoned action is at the core of critical thinking (Ennis, 2018).

The process of learning involves engaging in cognitive reflection and actively improving and monitoring skills to enhance proficiency in thinking (Lozano, Merrill, Sammalisto, Ceulemans, & Lozano, 2017; Lubna, Suhirman, & Prayogi, 2023). This can occur in inquiry-based learning within the context of Ethnoscience (Prayogi et al., 2022). Under specific circumstances, the process of reflection in the Ethnoscience context is regarded as an unusual occurrence within real-life issues inherent in cultural customs. This provides an opportunity for pedagogical intervention enabling critical thinking to be fostered. Students participate in a thorough analysis of the information by being presented with Ethnoscience through real-world challenges which allows them to build on their past understanding of traditional science (Zidny, Solfarina, Aisyah, & Eilks, 2021). When students are engaged in the exploration process within the context of Ethnoscience, their intellectual connections are faster in making relationships between knowledge because it is relevant to the cultural environment in which they have grown and developed (Zidny et al., 2021). It was demonstrated in an earlier study report that students' critical thinking skills may be developed and improved through the study of real-world events (Akmam, Anshari, Amir, Jalinus, & Amran, 2018).

Students' development of critical thinking begins with their understanding of the context in which they will study. Contextualizing science learning starts in the real world (King, 2012) and the most meaningful is when scientific exploration is linked to cultural contexts and local wisdom (Kurniawan & Syafriani, 2021). Its implementation in exploratory teaching contributes to the development of students' critical reflection (Zidny et al., 2021). Therefore, although Ethnoscience is not a new concept, it can be an innovative learning approach for sustainable development in science education (Eilks, 2015) especially in fostering students' critical thinking.

6. Conclusion

A study has been conducted to implement a blend of Ethnoscience and inquiry-based learning on a digital platform (e-learning) and assess its effect on the CT abilities of PSTs. Through experimentation, the combination of Ethnoscience and inquiry on the digital learning platform was found to be more effective in enhancing CT compared to traditional teaching methods. Descriptive analysis based on CTi and CTa parameters revealed that the CT abilities of PSTs improved from being less critical (before implementation) to very critical (after implementation) as indicated by a high increase in the n-gain scores. Statistical analysis showed a significant difference in CT outcomes between Ethnoscience-inquiry learning on the digital learning platform and the expository teaching method. These findings provide the primary reason why the blend of Ethnoscience and inquiry in the digital learning platform can be considered innovative learning to empower CT abilities.

7. Limitations

The limitations of this study should be acknowledged. Firstly, the research focuses on pre-service science teachers' (PSTs) critical thinking abilities within the specific context of the implemented blend of Ethnoscience and inquiry-based learning on a digital platform. The generalizability of the findings to different educational levels or disciplines remains to be explored. Secondly, the study demonstrates the effectiveness of the intervention in enhancing critical thinking abilities; it does not extensively investigate the factors influencing the observed improvements. Factors such as individual student characteristics, prior exposure to digital learning and the role of the instructors in facilitating the learning process could potentially impact the outcomes. Thirdly, the study's duration and intensity might have contributed to the observed improvements in critical thinking skills but the long-term effects and sustainability of these gains over time are not fully investigated. Lastly, the study acknowledges that the incorporation of Ethnoscience and local contexts played a vital role in enhancing critical thinking. However, the specific mechanisms through which these cultural elements contribute to improved critical thinking abilities are not extensively explored in this research. The study provides valuable insights into the potential of integrating Ethnoscience and inquiry-based learning on digital platforms for fostering critical thinking abilities among future science teachers despite these limitations.

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