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Integrating ethnoscience in inquiry-creative learning: a new breakthrough in enhancing critical thinking

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ABSTRACT

Incorporating knowledge of culture and local wisdom values (ethnosciences) into scientific investigation is a new breakthrough in the current study. The integration of ethnosciences and scientific investigation is a valuable pathway that serves not only as a tool for acquiring new knowledge but also for developing critical thinking (CT) skills essential in solving real-world problems. This research aims to enhance CT skills among prospective science teachers (PSTs) through a teaching program that integrates ethnosciences with inquiry-creative learning. This particular investigation employs a mixed method approach, combining both quantitative and qualitative methods. The quantitative study utilized a randomized pretest-posttest control group design, with traditional expository teaching employed as the comparison group. Qualitative methods were specifically used in this study through semi-structured interviews with lecturer, particularly regarding the PSTs engagement in the implementation of learning program. CT skill tests and interview forms were used as data collection instruments. The study findings reveal that integrating ethnosciences with inquiry-creative learning has a significant effect on the development of CT skills compared to traditional instruction. The findings highlight the effectiveness of this approach in improving CT skills among PSTs and contribute to future research in the field of science education.

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1. INTRODUCTION

Restoration of education and learning in sciences is necessary to prepare students for future careers, and has shifted from teaching knowledge to fostering critical thinking (CT) [1]. CT is now recognized as the most important skill in modern science education goals in the 21st century [2], [3]. Acquiring CT enables learners to discover truth from information and academic challenges [4]. However, practical learning often lacks a focus on developing CT skills due to conceptual differences and varied components [5]. Even professional teachers may struggle to effectively teach CT skills [6].

Numerous challenges afflict the realm of science education, particularly concerning the process of cultivating CT skills among students. CT does not naturally flourish on its own; rather, it necessitates a diverse array of stimuli that empower students to wield their cognitive faculties [7]. These stimuli are intertwined with a spectrum of inventive learning approaches within an appealing educational setting [8].

Past investigations [9] underscored that learning devoid of innovation fails to underpin students' mastery of critical and analytical thinking abilities.

Prospective science teachers (PSTs) play a crucial role as agents of change in improving education to cultivate students' CT skills in the future [10]. The university that offers science teacher education programs should prioritize the development of CT skills for PSTs and utilize CT intervention activities throughout their education [11]. The ultimate goal is for all forms of education and learning interventions to foster CT [12], [13].

A recent teaching approach known for developing CT skills involves incorporating local wisdom into a holistic learning process. That approach is now being tried to be implemented in the Indonesian education system, in line with the country's education standards [14]. Science education aims to understand natural phenomena, using inquiry-based teaching methods [15], [16]. However, the traditional understanding of inquiry as a purely theoretical concept does not align with the holistic learning approach [17]. Instead, the holistic science learning process integrates the wisdom values of local culture and is contextual in nature [18]. Ultimately, this type of learning is rooted in knowledge of cultural entities, also known as ethnosciences.

In recent times, there has been a notable evolution in the realm of inquiry learning, as it has embraced the integration of scientific creativity. As a result, a new educational approach has emerged, commonly referred to as inquiry-creative learning [19]. Previous research has explored the benefits of creative pedagogy in experimental models, emphasizing its role in fostering responsibility and creativity among students [20]. Nevertheless, there is a gap in the literature regarding the investigation of creative pedagogy within the inquiry model and its impact on improving CT performance. To address this gap, our research integrates ethnoscience with inquiry-creative learning to provide a comprehensive understanding of CT skills.

The purpose of the present investigation is to implement the learning process that integrates ethnosciences into inquiry-creative learning and assess how this approach influences the CT skills of PSTs. To establish a baseline for comparison, this research also includes a control group that receives instruction through traditional or expository teaching methods. The specific research questions are: i) what is the effect of the learning process that integrates ethnosciences into inquiry-creative learning on the CT skills of PSTs? and ii) what is the lecturer's response to the PSTs engagement in the learning process that integrates ethnoscience into creative-inquiry learning?

2. LITERATURE REVIEW

2.1. Critical thinking

In the modern era, it is anticipated that individuals should possess skills relevant to the 21st century. These skills enable them to effectively navigate swift changes and advancements, apply acquired information to their daily lives, secure a position within society, make sound decisions, maintain high productivity, and steer their personal trajectories [21]. The collection of proficiencies known as 21st century skills encompasses various facets and classifications, with CT skills standing out as one of the utmost importance [22]. As an essential skill, CT must be taught and trained to learner at all levels of education and learning programs [23].

CT is a psychological construct that is associated with cognitive activity. CT is defined as the ability to engage in reflective and logical thinking to make informed decisions [24], and it plays a crucial role in effective problem-solving [25]. Because CT is a cognitive activity, a number of indicators that show a person's ability to think critically have been formulated in CT standards [26], and the bias is towards four main indicators, namely skills in analyzing, evaluating, inferring, and decision making [27]. These indicators were also intensively used in previous studies [28]. The ability to think critically cannot develop naturally, therefore it must be enriched by various environmental stimuli and various atmospheres in the process of training it. Developing CT skills requires appropriate pedagogical interventions [29], [30], and can be fostered through the exploration of authentic problems that connect to students' experiences and scientific knowledge within their cultural context [27].

2.2. Ethnoscience

Ethnoscience, rooted in indigenous knowledge systems, encompasses the scientific exploration of culture [5]. Derived from "ethnos" (meaning nation) and "scientia" (meaning knowledge), it represents a culture-specific system of knowledge and cognition. Integration of cultural values and local wisdom with scientific principles highlights the inseparability of local traditions and knowledge [31]–[33]. Contextual experiences of learners are deeply influenced by ethnoscience, which bridges formal education and socio-cultural life. By providing practical applications and predictive capabilities, ethnoscience contributes to achieving learning objectives [34].

Previous research has indicated that incorporating ethnoscience into learning enhances students' scientific literacy and CT abilities [35], [36]. Ethnoscience serves as a useful tool for learners to investigate societal facts and phenomena in conjunction with science. Nonetheless, there is still a dearth of comprehensive research examining the extent to which incorporating ethnoscience in education enhances learners' thinking skills, resulting in challenges for many educators to promote CT [37]. The existing methods of education frequently fall short in fully integrating and assimilating local knowledge, leading to a significant learning challenge that demands immediate attention. Engaging students in the exploration of genuine ethnoscience-related issues offers a valuable approach to foster their CT skills development [14].

2.3. Inquiry-creative learning

Inquiry-creative learning is learning that integrates the attribution of creative processes (scientific creativity) to inquiry activities [19]. Giving creativity assignments can expand the range of students' scientific inquiry activities, so that students can apply, produce, find, compare, connect, and design their creative ideas [20]. Scientific creativity plays a significant role in science education, impacting various aspects of thinking and influencing students' cognitive development [38]. Recognizing the importance of creativity in student success, creative pedagogy has become an essential component of education [39]. However, traditional learning routines that neglect scientific creativity hinder students' knowledge construction and cognitive growth, necessitating the adoption of innovative approaches such as scientific investigations that optimize creativity [40]. The implementation of creative pedagogy is crucial for fostering higher-order thinking skills and achieving desired learning outcomes [39]. Neglecting scientific creativity in the learning process leads to stagnation akin to traditional learning, devoid of any significant improvements in learning performance [41].

Several factors support the empirical framework of the study related to the inquiry-creative learning. Firstly, inquiry learning aims to enhance students' thinking abilities [42], and prior studies have demonstrated its potential to develop CT skills in PSTs [7], [43]. Secondly, teaching the inquiry-creative process to PSTs has shown promise in nurturing their CT skills [44]. Lastly, interventions that incorporate ethnoscience, drawing upon local wisdom, have been identified as effective in training CT skills. Notably, the integration of ethnoscience and inquiry-creative learning to enhance CT skills in PSTs remains unexplored in the literature. Hence, the results of our research hold promise in enhancing the current body of knowledge, specifically regarding classroom learning encounters, and bolstering the CT skills of PSTs.

3. METHOD

3.1. Study design

This particular investigation employs a mixed method approach, combining both quantitative and qualitative data collection, analysis, and integration to achieve a comprehensive understanding. The study adopts an explanatory sequential design, a type of mixed method research that incorporates multiple data types, thereby reducing limitations associated with quantitative and qualitative analyses [45]. Initially, quantitative measurement tools were utilized for data collection through experimental design, followed by the collection and analysis of qualitative data to complement and elucidate the quantitative findings. The quantitative study utilized the “randomized pre- and post- test control group design” [46]. One experimental group and one control group (as a comparison) were included in this study. The experimental group received ethnoscience integrated with inquiry-creative learning (X), while the control group received traditional teaching (C). Each group were assessed for their CT skills through a pretest (O_1) and a posttest (O_2). The study design employed is outlined in (1):

$$\frac{\text{Intervention group A (Experimental) } O_1 \; X \; O_2}{\text{Intervention group B (Control) } O_1 \; X \; O_2} \tag{1}$$

To ensure impartiality among the groups, professional lecturers conducted the learning implementation simultaneously. Professional lecturers involved in this study understand the context and content of this research. In addition to administering pre-tests and post-tests, each group participated in four learning sessions over four weeks.

During the qualitative stage, lecturers were interviewed to gather their opinions and insights on the teaching process, specifically focusing on the involvement of PSTs in a learning approach that combines ethnoscience with creative-inquiry learning. These interviews were conducted after the implementation of the learning programs, aiming to gain a deeper understanding of their impact. The lecturers' responses and perceptions were sought through semi-structured interviews to gain valuable insights into the effectiveness of the learning initiatives.

3.2. Participants

This study involved PSTs studying at two universities in the Province of West Nusa Tenggara, Indonesia. The selection process for the participants was random using a purposive sampling technique [47], with the focus being on first-year PSTs enrolled in science specialist courses at these universities. A total of 45 PSTs participated in the study, with 22 assigned to intervention group A (experimental) and 23 to intervention group B (control). This sample size could be considered sufficient for a study employing a mixed methods approach, based on common considerations in statistical analysis and research design, especially if the expected effect size is medium to large [47]. Table 1 provides an overview of the participants' demographic details.

Table 1. The demographics of the participants

Demographic details		Experimental (n=22)		Control (n=23)	
		n	%	n	%
Gender	Male	12	55	8	35
	Female	10	45	15	65
Age (years)	<18	3	13.6	1	4.3
	18–19	18	82	20	87
	>19	1	4.4	2	8.7

3.3. Research instruments and procedure

This research utilizes instructional tools such as learning scenarios, teaching materials (modules), and worksheets to sustain the implementation of the integration of ethnosciences with inquiry-creative learning. The coverage of material as learning content is fluid mechanics which discusses: i) hydrostatic pressure (raising the issue of ethnoscience 'Bhukere,' the Bhuyakha Sentani tribe); ii) Archimedes' principle and the state of objects in fluids (raising the issue of ethnoscience 'Pasar Terapung' in South Kalimantan, and the seafaring tradition of the Bajo Tribe); iii) viscosity (raising the issue of ethnoscience 'Nyadep' and the tradition of processing palm sugar in Lombok); and iv) dynamic fluids (raising the issue of ethnoscience in the use of 'Cendi (Bong)' by the Sasak Tribe community).

The quantitative data collection instrument consisted of a CT skills test, while the qualitative data collection instrument included an interview guide, both serving as the primary research instruments. Prior to implementation, these instruments were validated by three science education experts to ensure their content and construct validity. Feedback from the validators confirmed the validity of the instructional tools and instruments. Therefore, these instruments were deemed adequate to sustain the implementation of learning programs.

To collect the CT skill data, an essay test instrument was employed. The assessment of CT skills focused on four indicators, namely: analysis, inference, evaluation, and decision-making. The test comprised eight items, the two items for each indicator. Scoring followed a multi-level approach (five scales), adapted from Ennis and Weir [48], with scores ranging from -1 (lowest) to +3 (highest). To collect data on CT skills, both sample groups were assessed using valid and reliable test instruments. The test was conducted twice: once before learning program (pre-test) and once after learning program (post-test). Both groups took the test simultaneously, with a time limit of 100 minutes for answering the questions.

After implementing the learning program, qualitative data was gathered through interviews with lecturers. The purpose of these interviews was to obtain feedback from the lecturers regarding the participation of PSTs during the implementation phase of the program. An interview guide was used as an instrument, which encompassed various aspects of the engagement of PSTs. These aspects included: i) motivation, the level of motivation demonstrated by PSTs; ii) autonomy, the extent to which PSTs displayed autonomy in accomplishing assigned tasks; iii) collaboration, the ability of PSTs to collaborate effectively with their peers in task development; iv) participation, the degree of involvement and relationships formed by PSTs with the subject matter, their lecturer, and fellow PSTs; v) resolution, the PSTs' problem-solving abilities when encountering challenges during class activities. The interviews with lecturers were recorded and subsequently transcribed.

3.4. Research data analysis

Descriptive and statistical analysis was conducted on the CT data, considering the CT score of participants on the pre- and post-test of each group. Descriptive analysis includes mean, standard deviation (SD), standard error of the mean (SE), and normalized gain (n-gain). The criteria for CT skills are based on the mean score of CT, ranging from not critical to very critical. The score range and CT criteria follow the guidelines of Suhirman and Prayogi [30]. The improvement of CT skills from pretest to posttest was examined for each utilizing Hake's n-gain formulation [49]. Descriptive plots are displayed to provide a clear overview of the improvement in CT scores between the pre-test and post-test in each group. Statistical analysis was conducted to compare the CT scores among the groups. The impact of the two learning interventions (experiment and control) on CT skills was assessed through an ANOVA test. By conducting an ANOVA test, researchers can statistically evaluate whether the observed differences in scores are due to the experimental manipulation or if they are merely random variations. This test allows for a comprehensive analysis of the data and assists in drawing conclusions about the effectiveness or impact of the experimental treatment on the CT skill measured outcomes. To analyze the qualitative data obtained from interview forms with lecturer, a content analysis was performed on the interview transcripts. The insights gained from the responses of lecturers regarding the implementation of learning in relation to motivation, autonomy, collaboration, participation, and resolution of PSTs provide valuable findings to complement the quantitative results.

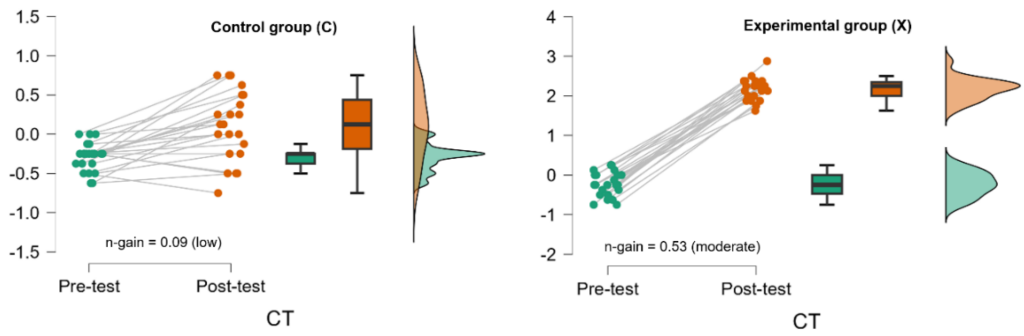
4. RESULTS AND DISCUSSION

4.1. The effect of learning programs on critical thinking skills

The results of the descriptive analysis of CT skills related to the study of implementing the inquiry-creative learning process that integrates ethnosciences are presented in Table 2, accompanied by descriptive plots of CT scores in each intervention group are presented in Figure 1. Figure 1(a) shows the descriptive plots of CT scores in control group and Figure 1(b) shows the descriptive plots of CT scores in experimental group. The pretest scores for CT skills for the control group were within the not critical criteria (M=-0.288, SD=0.179). The experimental group also acquired not critical criteria in the pretest (M=-0.288, SD=0.179). After the intervention of the learning process, both groups experienced an improvement in CT skill scores. The post-test scores for the experimental group, which underwent a learning process that integrates ethnosciences into inquiry-creative learning, acquired CT scores within the critical criteria (M=2.170, SD=0.277), showing a moderate increase in CT scores (n-gain=0.53). On the other hand, the post-test scores for the control group, which underwent traditional (expository) teaching intervention, acquired CT scores within the less critical criteria (M=0.103, SD=0.434), showing a low increase in CT scores (n-gain=0.09).

Table 2. The results of the descriptive analysis of CT skills from the groups

Groups		N	Mean	SD	SE	CT criteria
Pre-test	Control	23	-0.288	0.179	0.037	Not critical
	Experimental	22	-0.233	0.307	0.065	Not critical
Post-test	Control	23	0.103	0.434	0.091	Less critical
	Experimental	22	2.170	0.277	0.059	Critical



(a) (b)

Figure 1. Descriptive plots of CT scores in (a) control group and (b) experimental group

Furthermore, the ANOVA test was carried out, especially in relation to testing the differences in pretest and posttest scores between the experimental and control groups, this was to analyze and compare the average CT scores of the groups. In particular, it helps determine whether there is a significant variation between the mean CT scores of pretest and posttest measurements within each group, as well as whether there is a significant difference between the mean scores of the experimental group and the control group. Table 3 presents data from the ANOVA test results.

Table 3. The result of the ANOVA test

Cases	Sum of Sqrs.	df	Mean Sqr.	F	p	η^2
Within group (pre- post-test)						
Control	1.761	1	1.761	15.987	<0.001	0.267
Residuals	4.846	44	0.110			
Experimental	63.540	1	63.540	743.619	<0.001	0.947
Residuals	3.589	42	0.085			
Between group (exp. - cont.)						
Pre-test	0.034	1	0.034	0.548	0.463	0.013
Residuals	2.679	43	0.062			
Post-test	48.051	1	48.051	358.951	<0.001	0.893
Residuals	5.756	43	0.134			

There is a significant difference between the CT scores in the pre-test and post-test of the experimental group ($F=743.619$, $p<0.001$, $\eta^2=0.947$), as well as the control group (F15.987, $p<0.001$, $\eta^2=0.267$). This confirms the descriptive analysis results that in both groups, their CT scores improved from the pre-test to the post-test. Evaluating the average CT scores in the pre-test of both groups, the pre-test CT scores are not significantly different ($F=0.548$, $p=0.463$, $\eta^2=0.013$), meaning that the variance in average pre-test CT scores is uniform between the experimental and control groups. Meanwhile, the post-test CT scores are significantly different ($F=358.951$, $p<0.001$, $\eta^2=0.893$), confirming the descriptive analysis results that the average post-test CT scores of the experimental group are higher than those of the control group. These findings suggest that the learning process that integrates ethnosciences into inquiry-creative learning significantly impacts the CT skills of PSTs.

4.2. Lecturer's response to the learning program

A lecturer participated in this research. The lecturer stated that the program that integrates ethnosciences into inquiry-creative learning had a positive impact on efforts to improve the CT skills of PSTs. The involvement of the students highlighted in the interview is described:

> Motivation: "*The integration of ethnosciences, which focuses on indigenous knowledge and local cultural practices related to science, can spark PSTs' interest and engagement in the learning process. By incorporating their own cultural backgrounds and experiences, PSTs are more likely to be motivated to explore and understand scientific concepts. Integrating ethnosciences allows PSTs to see the practical applications of scientific knowledge in their own communities and cultural contexts. This connection to their daily lives enhances their motivation to learn and apply scientific principles in meaningful ways.*"
>
> Autonomy: "*I acknowledged that when PSTs are given the freedom to take ownership of their learning and engage in self-directed tasks, they demonstrate a higher level of autonomy. This autonomy empowers them to explore the subject matter of ethnosciences, which involves studying indigenous knowledge and cultural practices in relation to the natural world. By actively participating in inquiry-based and creative learning activities, PSTs develop their CT skills.*"
>
> Collaboration: "*When PSTs work together effectively with their peers in task development, they are able to exchange diverse perspectives, share knowledge, and collectively explore complex problems. This collaborative approach not only fosters a sense of community and inclusivity in the classroom but also enhances PSTs' ability to think critically, analyze information from different cultural perspectives, and develop innovative solutions.*"
>
> Participation: "*I observe the fact a higher degree of involvement and stronger relationships formed by PSTs with the subject matter, their lecturer, and fellow PSTs. The integration of ethnosciences not only sparked PSTs' curiosity but also encouraged them to actively engage in the learning process, fostering a deeper understanding and appreciation of different cultures and perspectives.*"
>
> Resolution: "*The learning programs have a favorable impact on efforts to enhance the PSTs' CT skills. I observed that by incorporating ethnosciences, which involve exploring indigenous knowledge, PSTs were not only able to develop innovative solutions to problems but also gained a deeper understanding of the subject matter. This holistic approach fostered a more comprehensive and analytical mindset among PSTs, allowing them to think critically.*"

The CT skills of science students are crucial for enhancing their deep understanding of scientific concepts. The initial assessment (pretest) of the two intervention groups, as shown in Table 2, revealed a lack of CT abilities among PSTs. This suggests that PSTs have not received sufficient training in developing their

CT skills during their learning experience. This finding is consistent with the results of Fitriani *et al*. [50] which indicated that universities' teaching practices do not prioritize the cultivation of CT skills, resulting in underdeveloped analytical abilities and CT skills among students. Similarly, previous study by Hsu [51] on students university in Taiwan found a need for educational reforms to promote CT, as the students' pre-assessment of CT skills demonstrated poor performance, falling short of the university's expectations.

In the present study, the implementation of inquiry learning, significantly expanded the opportunity for PSTs to develop their CT abilities. The intervention group A, which experienced ethnoscience integrated with inquiry-creative learning, demonstrated a notably higher level of CT, as indicated by their CT scores, compared to intervention group B, which received traditional teaching methods. Figure 1 visually depicts the superior CT scores achieved by intervention group A in contrast to the minimal increase observed in group B (with a low n-gain of 0.09). This enhancement in CT skills can be attributed to the scientific-creativity interventions implemented. These findings align with previous research that suggests intervention through scientific creativity in inquiry teaching enhances analytical skills in prospective teachers [44]. Overall, inquiry learning surpasses traditional teaching methods, which is consistent with the findings of Sellars *et al*. [52] who concluded that inquiry learning outperforms traditional teaching in improving students' skills and learning outcomes.

The participants in both intervention groups initially demonstrated a lower level of CT skills on the pretest. However, the posttest revealed varied improvements in CT skills. Specifically, intervention group A exhibited superior performance at a critical level, while group B showed the low improvement, they at a less critical level. The largest enhancement in CT scores (base on n-gain parameter) was observed in intervention group A. Statistical analysis, as shown in Table 3, confirmed a significant difference in CT scores between the groups. It can be inferred that traditional teaching led to a small increase in CT scores, while ethnoscience integrated with inquiry-creative learning proved to be superior. Even compared to other cooperative teaching methods like student teams-achievement divisions (STAD), the inquiry learning was found to be more effective in developing CT skills [53]. The combination of ethnoscience and inquiry-creative learning integration offers several advantages compared to traditional teaching methods. For the purposes of this research, traditional teaching refers to expository teaching [54]. In contrast, inquiry-creative learning is informed by the advancements outlined in the recent studies by Wahyudi *et al*. [19] and further enhanced through the integration of ethnoscience principles.

The integration of ethnoscience with inquiry-creative learning offers significant advantages over traditional teaching methods when it comes to developing CT skills in PSTs. Firstly, the initial phase of problem finding during ethnoscience exploration encourages PSTs to identify numerous authentic issues and discrepant events. This broadens their thinking by considering multiple problem perspectives and stimulates creative ideas. Scientific creativity in problem identification positively influences CT skills in students [55], emphasizing the importance of creatively finding and solving problems in inquiry-based instruction [56], [57]. Secondly, stimulating creative thinking in PSTs through hypothesizing and designing innovative experiments related to ethnoscience enhances their deeper understanding and knowledge acquisition. Creative experimentation strengthens scientific knowledge and process skills, ultimately impacting CT abilities [41]. Thirdly, evaluating creative experimental procedures in ethnoscience reinforces CT. This process requires students to demonstrate imaginative capabilities and creative thinking skills, resulting in improved CT abilities [58]. Fourthly, the presentation of scientific-creative products related to ethnoscience serves as a tangible outcome of PSTs' CT skills. As long as these products are developed through creative experimentation, they can be considered as manifestations of CT. Ultimately, all forms of ethnoscience integrated with inquiry-creative learning exhibit a superior effect on supporting PSTs' CT skills of compared to expository or traditional teaching approaches. This is supported by previous studies by Zidny *et al.* [59] that inquiry into ethnoscience cases makes learning more meaningful and contextual which can train students to improve their thinking abilities.

It is important to highlight that the inquiry teaching approach popularized by Arends [42] differs from the ethnoscience integrated with inquiry-creative learning employed in the current study. The inquiry teaching approach focuses on a single problem or discrepant event, which may not be engaging for students due to their diverse learning experiences [42]. Previous research [60] has also shown that students struggle with manipulating their ideas in inquiry-based learning, leading to a reliance on teacher instructions. It can hinder the development of students' initiative and CT skills [61]. This study addresses this weakness by integrating ethnoscience with inquiry-creative learning, allowing PSTs to freely manipulate their creative ideas while addressing various issues. By emphasizing the importance of applying ethnoscience integrated with inquiry-creative learning, this study provides valuable insights for enhancing CT skills in PSTs.

The results of the qualitative study through interviews with the lecturers presented highlight the positive impact of integrating ethnosciences into inquiry-creative learning on the efforts to improve the CT skills of pre-service teachers. The lecturer who participated in the research provided insights into how the involvement of PSTs in this program influenced their motivation, autonomy, collaboration, participation, and resolution. Motivation was identified as a key outcome of integrating ethnosciences into inquiry-creative learning. By incorporating indigenous knowledge and local cultural practices related to science, PSTs were able to connect their own cultural backgrounds and experiences to scientific concepts. This connection to their daily lives increased their motivation to explore and understand scientific principles. Seeing the practical application of scientific knowledge in their own communities and cultural contexts enhanced their motivation to learn and apply scientific principles in meaningful ways. A literature review [62] indicates that studies related to the integration of ethnosciences in education can enhance students' learning motivation.

Autonomy was found to be empowered when PSTs were given the freedom to take ownership of their learning and engage in self-directed tasks. The subject matter of ethnosciences, which involves studying indigenous knowledge and cultural practices in relation to the natural world, provided an opportunity for PSTs to actively participate in inquiry-based and creative learning activities. This active engagement fostered their CT skills by allowing them to explore and develop their understanding of the subject matter. Student autonomy in learning is a strong predictor of the development of thinking processes [63]. In addition to strengthening thinking skills, previous studies also support the current findings that a learning framework that integrates ethnosciences can foster student autonomy in learning science [64]. Inquiry-based teaching also strongly supports the creation of student autonomy in exploring scientific concepts [65].

Collaboration played a crucial role in enhancing PSTs' CT skills. Effective collaboration with peers in task development enabled the exchange of diverse perspectives and knowledge sharing [66]. This collaborative approach not only created a sense of community and inclusivity in the classroom but also contributed to PSTs' ability to think critically, analyze information from different cultural perspectives, and develop innovative solutions. Collaborative learning provided a platform for students to engage in higher-order thinking and develop a more comprehensive understanding of the subject matter [67]. Effective collaborative learning has been found to have a positive impact on students' development of CT skills [68]. Inquiry activities carried out collaboratively help learners develop deep thinking about their creative ideas [69]. This is an important part of ways to develop CT.

Participation was observed to be significantly increased when ethnosciences were integrated into the learning program. PSTs exhibited a higher degree of involvement and formed stronger relationships with the subject matter, lecturers, and fellow PSTs. The integration of ethnosciences sparked PSTs' curiosity and encouraged them to actively engage in the learning process, leading to a deeper understanding and appreciation of different cultures and perspectives. This active participation fostered a more holistic and analytical mindset among PSTs, allowing them to think critically. This is as discussed by Ayçiçek [70] that student participation during the learning process in the classroom is an important step in developing CT.

Resolution, in terms of developing CT skills, was achieved through the holistic approach of integrating ethnosciences into inquiry-creative learning. By exploring indigenous knowledge and cultural practices, PSTs were not only able to develop innovative solutions to problems but also gained a deeper understanding of the subject matter. This comprehensive and analytical mindset fostered CT among PSTs, enabling them to think critically and apply their knowledge and skills in various contexts. Knowledge of evolving ethical and cultural values, when adequately explored, influences broader CT resolutions [71]. Ways of CT in solving science problems will develop if learners are faced with a number of challenges that require proper resolution [72].

In conclusion, the research results indicate that the integration of ethnosciences into inquiry-creative learning has a positive impact on PSTs' efforts to improve their CT skills. By connecting scientific concepts to their cultural backgrounds and experiences, PSTs become more motivated to explore and understand scientific principles. The freedom to engage in self-directed tasks and the opportunity to explore indigenous knowledge and cultural practices empower PSTs to develop their CT skills. Collaborative learning and active participation promote CT and the development of innovative solutions. Overall, the integration of ethnosciences into inquiry-creative learning provides a comprehensive and analytical approach that fosters CT skills among PSTs.

The findings of this research have significant practical implications for educational practice and policy. Firstly, integrating ethnosciences into inquiry-creative learning offers a promising approach to enhancing CT skills among PSTs. By incorporating local wisdom and cultural values into scientific investigation and creative learning, educators can create a more engaging and relevant learning environment that encourages PSTs to explore authentic issues, develop innovative solutions, and deepen their understanding of scientific concepts within cultural contexts. This approach not only fosters CT skills but also promotes motivation, autonomy, collaboration, participation, and resolution among PSTs. Therefore, educational institutions and policymakers should consider integrating ethnosciences into inquiry-creative learning as a part of science teacher education programs to better prepare PSTs for addressing real-world problems and promoting inclusive and culturally responsive science education.

5. CONCLUSION

The current study has implemented ethnoscience integrated with an inquiry-creative learning. Performance assessments of PSTs using CT have been conducted. The results indicate that the program integrating ethnoscience with inquiry-creative learning demonstrates a better effect on the PSTs' CT skills compared to traditional teaching. Statistical analysis confirms a significant difference in CT skills performance between the two learning interventions. These findings highlight the effectiveness of learning practices that combine ethnoscience integrated with inquiry-creative learning in enhancing the CT skills of PSTs. By connecting scientific concepts to their cultural backgrounds and experiences, PSTs become more motivated to explore and understand scientific principles. The freedom to engage in self-directed tasks and the opportunity to explore indigenous knowledge and cultural practices empower PSTs to develop their CT skills. Collaborative learning and active participation promote CT and the development of innovative solutions. Overall, the integration of ethnosciences into inquiry-creative learning provides a comprehensive and analytical approach that fosters CT skills among PSTs.

Integrating ethnosciences with scientific investigation and creative learning is portrayed as a valuable pathway not only for acquiring new knowledge but also for nurturing CT skills vital in addressing real-world problems. This integration stands out theoretically from traditional methods as it emphasizes a holistic approach that incorporates local wisdom and cultural values, thereby contextualizing learning experiences for PSTs. Unlike traditional theoretical inquiry, which may lack engagement and relevance to students' diverse backgrounds, Inquiry-Creative learning integrated with ethnoscience encourages students to identify authentic issues, stimulates creative ideas, and fosters deeper understanding through hypothesis-driven experimentation and evaluation of creative solutions within cultural contexts. This approach not only enhances motivation, autonomy, collaboration, participation, and resolution among PSTs but also offers a more comprehensive and analytical framework for developing CT skills compared to traditional expository teaching methods.

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