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Place-based Socioscientific Issues Approach to Enhance Prospective Natural Sciences Teachers' Critical Reasoning

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Abstract. Critical reasoning plays a crucial role in analyzing and evaluating available information and in formulating appropriate solutions to issues arising in communities today. This role can be enhanced through a place-based socioscientific issues (SSI) approach. This study aims to enhance prospective natural sciences teachers' critical reasoning through a place-based SSI approach in West Kalimantan in two contexts: the use of *kratom* (*Mitragyna speciosa* Korth.) and *tuak* (rice wine). This study employed a quasi-experimental, non-equivalent control group pretest–posttest design and involved 64 students at Universitas Tanjungpura. Data were collected using a test comprising critical reasoning dimensions: information evaluation, complexity identification, information sources credibility assessment, and multiperspective. The profile of prospective natural sciences teachers' critical reasoning showed improvement across all dimensions. The effectiveness of the place-based SSI approach showed a statistically significant improvement (p-value < 0.05) on the dimensions of complexity identification (large effect size), information sources credibility assessment (medium effect size), and multiperspective (medium effect size). The information evaluation dimension was insignificantly different (p-value > 0.05), despite a medium effect size. The findings show that a place-based SSI approach is effective for enhancing prospective natural sciences teachers' critical reasoning. This study strengthens the SSI-based learning literature, develops scientifically literate citizens, and increases the quality of teacher education programs. Furthermore, this study contributes to Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), by increasing the number of individuals with the skills necessary to navigate the ever-changing times and by enhancing the quality of prospective natural sciences teachers in West Kalimantan.

Keywords: Critical reasoning; *Mitragyna speciosa*; place-based socioscientific; rice wine; socioscientific issues

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INTRODUCTION

Modern human civilization is constantly facing a rapid escalation of various issues emerging across fields directly related to human well-being on a global scale, such as health (Tong et al., 2022), economy (Cabrero & Elizondo, 2016), technology (Kumari & Oman, 2025), and environment (Cao et al., 2025). These issues contribute to transforming education, shifting the focus from mastering concepts to a framework that prepares students to make informed decisions about complex sociocultural dilemmas. The complex issues arising amid the planetary crisis over time demand that society at large be able to evaluate evidence and consider ethical implications, exploring how principles and virtues can influence daily life (Högström et al., 2025). In this context, the study of the natural sciences plays a crucial role, as many contemporary societal issues are closely intertwined with concepts from natural sciences (Fernández et al., 2022). Consequently, the teaching of natural sciences should no longer focus solely on rote memorization but also foster higher-order thinking skills-based competencies (Santiani et al., 2023). One such skill that must be continuously developed is critical reasoning.

Critical reasoning is essential in today's world to navigate the flood of contradictory information in a society now immersed in a digital and knowledge-based environment (Zlatkin-

Troitschanskaia et al., 2020). Therefore, critical reasoning is an essential skill for students to master in 21st-century education. Critical reasoning is the skill of rational, systematic analysis of information, evaluation of arguments, and active, creative problem-solving based on credible evidence and facts (Rahaju et al., 2026; Yokhebed et al., 2024b). Given the key focus on prospective natural sciences teachers' competencies, critical reasoning is particularly important, as teachers are expected to master natural sciences concepts and guide students to critically and responsibly analyze various controversial scientific phenomena. Several studies indicate the need for learning practices in teacher education programs that focus on the reasoning processes that should be mastered rather than merely the transmission of knowledge (e.g., Smith & Paradise, 2022; Stammen et al., 2018). In fact, critical reasoning is key to academic and professional success because it plays a role in strengthening analytical, decision-making, and adaptive skills in a constantly changing environment (Fabio et al., 2025). One pedagogical approach to enhance prospective natural sciences teachers' critical reasoning is the use of socioscientific issues (SSI).

Socioscientific issues (SSI) refer to dilemmas that arise at the intersection of scientific and sociocultural considerations, indicating intricate and complex relationships (Herman et al., 2022; Viehmann et al., 2024). Through the SSI approach, prospective natural sciences teachers are encouraged to engage in argumentation, evidence evaluation, perspective-taking, and reflective decision-making. The SSI approach has been shown to positively impact the professional development of prospective teachers by enhancing content knowledge (Namdar et al., 2025), decision-making quality (Lin et al., 2023), and sense of efficacy (Yahaya et al., 2015). Nevertheless, the implementation of the SSI approach generally remains generic and detached from the sociocultural environment surrounding prospective natural sciences teachers because it revolves only around global examples found in international cases. Therefore, current educational discourse increasingly emphasizes the importance of place-based SSI. The use of place-based SSI facilitates learning by connecting scientific concepts to real-world issues occurring in the community and surrounding environment, emphasizing contextuality and familiarity within the environment of prospective natural sciences teachers (Gezer et al., 2024; Muslu & Isik, 2024). By contextualizing learning within familiar settings, prospective natural sciences teachers are more likely to engage more deeply with the SSI presented. This contextual relevance is considered crucial for strengthening the critical reasoning of prospective natural sciences teachers, given their proximity to the issues being addressed.

The place-based SSI approach, therefore, offers tremendous potential to enhance the critical reasoning of prospective natural sciences teachers. Although learning using the place-based SSI approach is on the rise, studies investigating its use in enhancing critical reasoning among prospective natural sciences teachers remain limited. Existing studies predominantly focus on secondary school students (e.g., Yokhebed et al., 2024b). Therefore, this study aims to address this gap by applying a place-based SSI approach to enhance the critical reasoning of prospective natural sciences teachers—specifically, prospective teachers at Universitas Tanjungpura. This study offers a novelty by applying a place-based SSI approach to two local potentials in West Kalimantan: the cultivation and use of *kratom* (*Mitragyna speciosa* Korth.) as traditional medicine and the consumption of *tuak* (rice wine), which have not been previously investigated. The selection of these two issues is based on the strong interconnections among biological, health, environmental, economic, regulatory, and cultural aspects, which contain both pros and cons for society and reflect the richness of local biodiversity, giving rise to SSI debates over their utilization. This study contributes to the development of science and society by providing theoretical support for the growing discourse on SSI-based learning and offering practical implications for developing contextual and transformative pedagogical practices in teacher education programs. Furthermore, this study is expected to support the development of scientifically literate citizens and bridge the persistent gap between academic science and community realities.

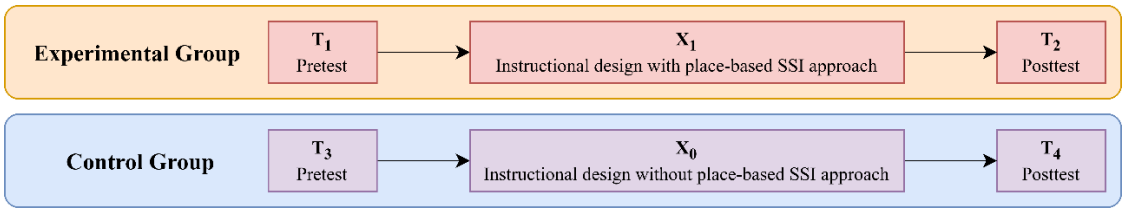


Figure 1. Non-equivalent control group pretest–posttest design

METHODS

Study Design

This study was conducted at Universitas Tanjungpura, Pontianak, West Kalimantan, Indonesia, in 2024. The method used was quantitative. This study used a quasi-experimental, non-equivalent control group pretest–posttest design (Figure 1). Through this design, the study examined how the independent variable (instructional design with a place-based SSI approach) could influence the dependent variable (prospective natural sciences teachers' critical reasoning). Before the experiment was conducted, the students were given a pretest, followed by the treatment. A posttest was administered after the treatment, and the differences between the pretest and posttest results were analyzed.

Population and Sample

The population for this study consisted of students enrolled in the 2024/2025 academic year in the Department of Mathematics and Natural Sciences Education, Faculty of Teacher Training and Education, Universitas Tanjungpura. Using cluster random sampling of students enrolled in the Introductory Biology course, a sample of 64 students was selected. Based on the assumption that each student in the sample had homogeneous abilities, an experimental group of 30 students from the Physics Education study program and a control group of 34 students from the Biology Education study program were formed. The demographics of the sample, by gender and regency of origin, are presented in Table 1, indicating that the entire sample came from West Kalimantan and thus had a high level of familiarity with the SSI under discussion.

Course Design

This study was conducted in the Introductory Biology course included in the curriculum of the Physics Education (KPF 402) and Biology Education (BIO 400) study programs at Universitas Tanjungpura. The Introductory Biology course in both study programs is worth 2 credits and consists of 16 meetings over one semester. Each credit is equivalent to 50 minutes of face-to-face activities, 60 minutes of structured assignments, and 60 minutes of self-study activities. This study was conducted on the topic of "Scientific Methods," with two meetings dedicated to this topic in both the experimental and control groups.

Table 1. Demographic profile of the participants in experimental and control groups by gender and regency

No.	Criterion	Group	Group	
			Experimental	Control
1	Gender	Female	24 (80.00%)	31 (91.18%)
		Male	6 (20.00%)	3 (8.82%)
2	Regency	Bengkayang	2 (6.67%)	2 (5.88%)
		Kapuas Hulu	4 (13.33%)	4 (11.76%)
		Kayong Utara	2 (6.67%)	4 (11.76%)
		Ketapang	1 (3.33%)	0 (0.00%)
		Kubu Raya	4 (13.33%)	8 (23.53%)
		Landak	4 (13.33%)	2 (5.88%)
		Melawi	1 (3.33%)	1 (2.94%)
		Mempawah	0 (0.00%)	1 (2.94%)
		Sambas	7 (23.33%)	7 (20.59%)
		Sanggau	3 (10.00%)	3 (8.82%)
		Sekadau	2 (6.67%)	1 (2.94%)
		Singkawang	0 (0.00%)	1 (2.94%)

Table 2. Example items representing each critical reasoning dimension

No.	Dimension	Example Item	
		Number	Question
1	Information evaluation	2b	Based on the information from the sources or websites you read, is there any information that contradicts the theories or concepts you have learned?
2	Complexity identification	1a	Based on the text above, identify the controversial issues (those that spark debate) in society regarding *kratom* leaves!
3	Information sources credibility assessment	4c	Has the finding that "*kratom* is 13 times more dangerous than morphine" been verified by experts? How have the results of this study been reported in journals, magazines, newspapers, or other media? Provide evidence!
4	Multiperspective	5a	In your opinion, what actions and solutions should stakeholders propose to address the issues discussed above? Explain!

The topic "Scientific Methods" was selected because scientific methods serve as the foundation for conducting systematic investigations to acquire knowledge and as a cognitive framework that enables prospective natural sciences teachers to analyze and evaluate complex issues rationally. Furthermore, scientific methods hold a fundamental position because they provide a basis for evidence-based decision-making. The local SSI in West Kalimantan highlighted in this study encourages prospective natural sciences teachers to test the credibility of information, evaluate various perspectives, consider sociocultural standpoints, and construct logical arguments regarding these issues.

Data Collection Techniques

Data collection in this study was conducted using a test as the instrument. The test was developed based on the four dimensions of critical reasoning proposed by Yokhebed et al. (2024b): information evaluation, complexity identification, information sources credibility assessment, and multiperspective. The test contained five essay-type items, with items 1, 2, 4, and 5 containing several sub-items. Before use, the test containing the dimensions of critical reasoning was validated by two Biology Education lecturers at Universitas Tanjungpura and met Gregory's (2015) validity index criteria. In addition, the test's reliability was assessed with Cronbach's alpha. Example items from each dimension of critical reasoning are presented in Table 2.

Data Analysis Techniques

The data analysis techniques used in this study are intended to address two aspects to be unveiled. The first aspect—profile of prospective natural sciences teachers' critical reasoning in the experimental group—is analyzed by converting scores to grades obtained in each dimension of critical reasoning using descriptive statistics in Microsoft Excel 2019. The second aspect—effectiveness of place-based SSI in enhancing prospective natural sciences teachers' critical reasoning—used descriptive and inferential statistics, conducted with Statistical Product and Service Solutions version 26. Descriptive statistics were used to describe achievement in critical reasoning among prospective natural sciences teachers based on posttest scores. Meanwhile, inferential statistics were used to determine the difference in means between the experimental and control groups. The prerequisite analyses included normality and homogeneity tests; the normality test used the Shapiro–Wilk test, and the homogeneity test used Levene's test. After the prerequisite analyses were conducted and the pretest and posttest data met the criteria, data analysis proceeded with a t-test. The t-test results indicated a significant difference between the experimental and control groups. Next, the effect size for the experimental group was calculated using Cohen's d for each dimension of critical reasoning, which was then categorized as small ($d \leq 0.2$), medium ($0.2 < d < 0.8$), or large ($d \geq 0.8$) (Cohen, 1988).

RESULTS AND DISCUSSION

The place-based SSI approach is a pedagogical practice that integrates socioscientific problem-solving with the local contexts surrounding prospective natural sciences teachers. Finkenstaedt-Quinn et al. (2026) emphasize that locally relevant SSI content can provide specific contexts to support the emergence of learning activities focused on matters recognized as crucial

to daily lives and activities, thereby increasing citizens' engagement with science compared to traditional learning approaches that merely focus on the acquisition of conceptual knowledge. Furthermore, Viehmann et al. (2024) argue that the use of the SSI approach can improve the quality of natural sciences learning by enhancing higher-order thinking skills-based competencies and strengthening interdisciplinary learning, thereby preparing individuals capable of addressing various challenges in a complex society through scientific inquiry. Consequently, the place-based SSI approach holds tremendous potential for enhancing the critical reasoning of prospective natural sciences teachers.

Critical reasoning is now receiving increasing attention in the context of education in Indonesia, which currently places a strong emphasis on improving reasoning and problem-solving skills (Rahaju et al., 2026). This is supported by de los Santos et al. (2025), who state that natural sciences learning requires the development of thinking skills through the ability to analyze and evaluate evidence and formulate relevant hypotheses. Within the place-based SSI approach, critical reasoning plays an extraordinary role because SSI generally involves problem-solving based on various standpoints through scientifically verified evidence while considering the principles and virtues stemming from societal, cultural, and ethical implications. Therefore, enhancing critical reasoning among prospective natural sciences teachers is crucial to support their cognitive development and prepare educators capable of designing and implementing reflective, contextual, and socially responsive learning. Table 3 presents the dimensions of critical reasoning in this study, based on Yokhebed et al. (2024b).

In this study, the integration of locally relevant SSI for prospective natural sciences teachers in West Kalimantan provides them with opportunities to engage critically with controversial issues in their surrounding environment. The SSI topics addressed are the cultivation and use of *kratom* as traditional medicine and the consumption of *tuak*. To provide a clearer representation of the SSI utilized in the experimental group, Figure 2 illustrates *kratom* and *tuak* (obtained from personal documentation, presented with the intention to provide the appropriate visual representations for the readers). Both issues have long been present in the sociocultural landscape of West Kalimantan and continuously spark debates within the community involving biological, health, environmental, economic, regulatory, and cultural aspects. *Kratom* has long been used as traditional medicine by various communities and has become an important economic commodity in ensuring community well-being (Budiarti et al., 2025). However, the use of *kratom* remains controversial due to its pharmacological effects, which tend to have negative consequences (as demonstrated in a study by Panjaitan & Liridah, 2021). A similar situation is indicated by *tuak*. *Tuak* is an alcoholic beverage generally associated with social interactions and traditional ceremonies (Murhaini & Achmadi, 2021), but has been shown to have negative health impacts (e.g., causing liver damage, as demonstrated in a study by Panjaitan & Mery, 2023). Thus, the use of these two SSI suggests that a place-based SSI approach can serve as a pedagogical approach capable of fostering meaningful, evidence-based learning for prospective natural sciences teachers in West Kalimantan.

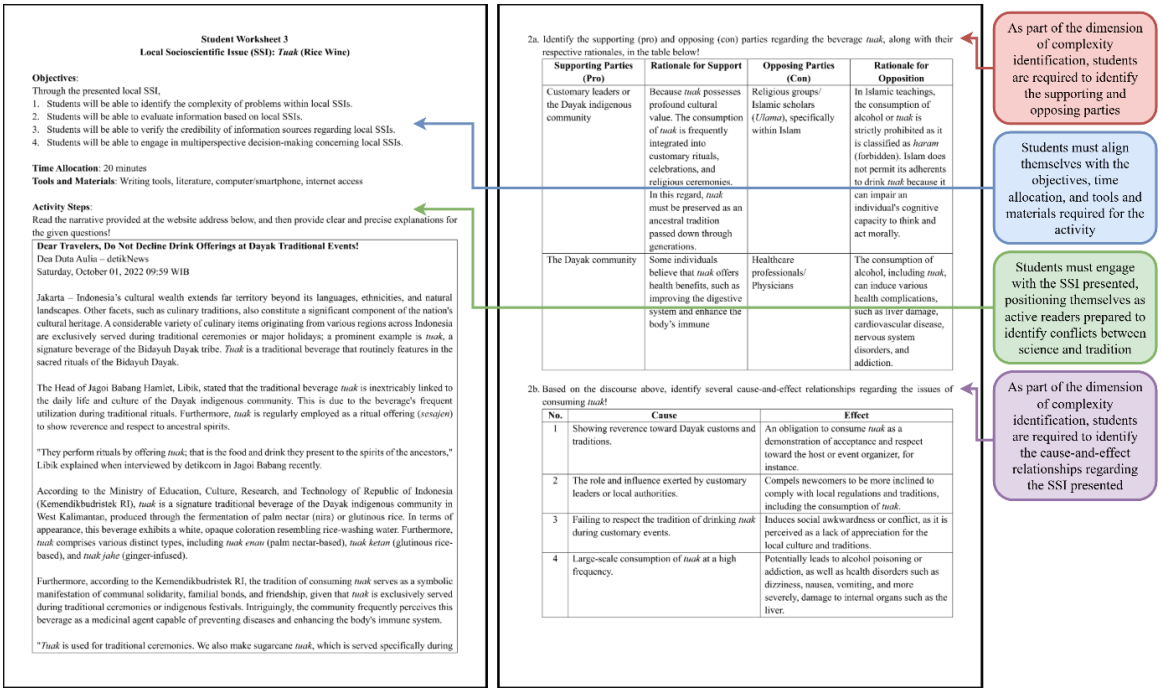
Table 3. Description of each critical reasoning dimension

No.	Dimension	Description
1	Information evaluation	Prospective natural sciences teachers' ability to verify the accuracy of information based on reliable sources
2	Complexity identification	Prospective natural sciences teachers' ability to identify cause-and-effect relationships, pros and cons, or connections between social and scientific aspects in SSI
3	Information sources credibility assessment	Prospective natural sciences teachers' ability to identify reliable information sources
4	Multiperspective	Prospective natural sciences teachers' ability to identify the perspectives of stakeholders involved in SSI

(a) (b)

Figure 2. The SSI addressed in the experimental group: (a) *kratom* and (b) *tuak*

The instructional design for the experimental group was explicitly designed to emphasize a place-based SSI approach grounded in the selected SSI: *kratom* and *tuak*. The learning process began with the presentation of SSI sourced from various online media (such as news articles) to stimulate prospective natural sciences teachers' curiosity and engagement with the selected SSI. Subsequent learning activities continued as prospective natural sciences teachers identified key issues, analyzed the complexity of the presented SSI, and explored causal relationships from various standpoints—primarily biological, health, environmental, economic, regulatory, and cultural. To support critical reasoning, which is, of course, based on credible evidence, prospective natural sciences teachers are guided to search for and examine information from multiple sources to evaluate its credibility. Prospective natural sciences teachers are also instructed to compare claims from various perspectives; consequently, they discuss the relevant stakeholders for the SSI issues raised and formulate potential solutions. Throughout the learning activities, prospective natural sciences teachers are encouraged to apply principles of critical reasoning, thereby enhancing their performance across each dimension. Learning activities also center on group discussions, roleplaying, presentations, and reflections that allow prospective natural sciences teachers to communicate their arguments, consider various existing perspectives, and formulate informed decisions to address the SSI raised. The implementation of learning activities is further supported by the use of worksheets (see Figure 3 for an example for the *tuak* context).



Student Worksheet 3
Local Socioscientific Issue (SSI): *Tuak* (Rice Wine)

Objectives:
Through the presented local SSI,
1. Students will be able to identify the complexity of problems within local SSIs.
2. Students will be able to evaluate information based on local SSIs.
3. Students will be able to verify the credibility of information sources regarding local SSIs.
4. Students will be able to engage in multiperspective decision-making concerning local SSIs.

Time Allocation: 20 minutes
Tools and Materials: Writing tools, literature, computer/smartphone, internet access

Activity Steps:
Read the narrative provided at the website address below, and then provide clear and precise explanations for the given questions!

Dear Travelers, Do Not Decline Drink Offerings at Dayak Traditional Events!
Dea Duta Aulia – detikNews
Saturday, October 01, 2022 09:59 WIB

Jakarta – Indonesia's cultural wealth extends far territory beyond its languages, ethnicities, and natural landscapes. Other facets, such as culinary traditions, also constitute a significant component of the nation's cultural heritage. A considerable variety of culinary items originating from various regions across Indonesia are exclusively served during traditional ceremonies or major holidays; a prominent example is *tuak*, a signature beverage of the Bidayuh Dayak tribe. *Tuak* is a traditional beverage that routinely features in the sacred rituals of the Bidayuh Dayak.

The Head of Jagoi Babang Hamlet, Libik, stated that the traditional beverage *tuak* is inextricably linked to the daily life and culture of the Dayak indigenous community. This is due to the beverage's frequent utilization during traditional rituals. Furthermore, *tuak* is regularly employed as a ritual offering (*sesajen*) to show reverence and respect to ancestral spirits.

"They perform rituals by offering *tuak*; that is the food and drink they present to the spirits of the ancestors," Libik explained when interviewed by detikcom in Jagoi Babang recently.

According to the Ministry of Education, Culture, Research, and Technology of Republic of Indonesia (Kemendikbudristek RI), *tuak* is a signature traditional beverage of the Dayak indigenous community in West Kalimantan, produced through the fermentation of palm nectar (nira) or glutinous rice. In terms of appearance, this beverage exhibits a white, opaque coloration resembling rice-washing water. Furthermore, *tuak* comprises various distinct types, including *tuak enau* (palm nectar-based), *tuak ketan* (glutinous rice-based), and *tuak jahe* (ginger-infused).

Furthermore, according to the Kemendikbudristek RI, the tradition of consuming *tuak* serves as a symbolic manifestation of communal solidarity, familial bonds, and friendship, given that *tuak* is exclusively served during traditional ceremonies or indigenous festivals. Intriguingly, the community frequently perceives this beverage as a medicinal agent capable of preventing diseases and enhancing the body's immune system.

"*Tuak* is used for traditional ceremonies. We also make sugarcane *tuak*, which is served specifically during

2a. Identify the supporting (pro) and opposing (con) parties regarding the beverage *tuak*, along with their respective rationales, in the table below!

Supporting Parties (Pro)	Rationale for Support	Opposing Parties (Con)	Rationale for Opposition
Customary leaders or the Dayak indigenous community	Because *tuak* possesses profound cultural value. The consumption of *tuak* is frequently integrated into customary rituals, celebrations, and religious ceremonies.	Religious groups/ Islamic scholars (*Ulama*), specifically within Islam	In Islamic teachings, the consumption of alcohol or *tuak* is strictly prohibited as it is classified as *haram* (forbidden). Islam does not permit its adherents to drink *tuak* because it
	In this regard, *tuak* must be preserved as an ancestral tradition passed down through generations.		can impair an individual's cognitive capacity to think and act morally.
The Dayak community	Some individuals believe that *tuak* offers health benefits, such as improving the digestive	Healthcare professionals/ Physicians	The consumption of alcohol, including *tuak*, can induce various health complications,
	system and enhance the body's immune		such as liver damage, cardiovascular disease, nervous system disorders, and addiction.

2b. Based on the discourse above, identify several cause-and-effect relationships regarding the issues of consuming *tuak*!

No.	Cause	Effect
1	Showing reverence toward Dayak customs and traditions.	An obligation to consume *tuak* as a demonstration of acceptance and respect toward the host or event organizer, for instance.
2	The role and influence exerted by customary leaders or local authorities.	Compels newcomers to be more inclined to comply with local regulations and traditions, including the consumption of *tuak*.
3	Failing to respect the tradition of drinking *tuak* during customary events.	Induces social awkwardness or conflict, as it is perceived as a lack of appreciation for the local culture and traditions.
4	Large-scale consumption of *tuak* at a high frequency.	Potentially leads to alcohol poisoning or addiction, as well as health disorders such as dizziness, nausea, vomiting, and more severely, damage to internal organs such as the liver.

As part of the dimension of complexity identification, students are required to identify the supporting and opposing parties

Students must align themselves with the objectives, time allocation, and tools and materials required for the activity

Students must engage with the SSI presented, positioning themselves as active readers prepared to identify conflicts between science and tradition

As part of the dimension of complexity identification, students are required to identify the cause-and-effect relationships regarding the SSI presented

Figure 3. Excerpt of the worksheet for the *tuak* context

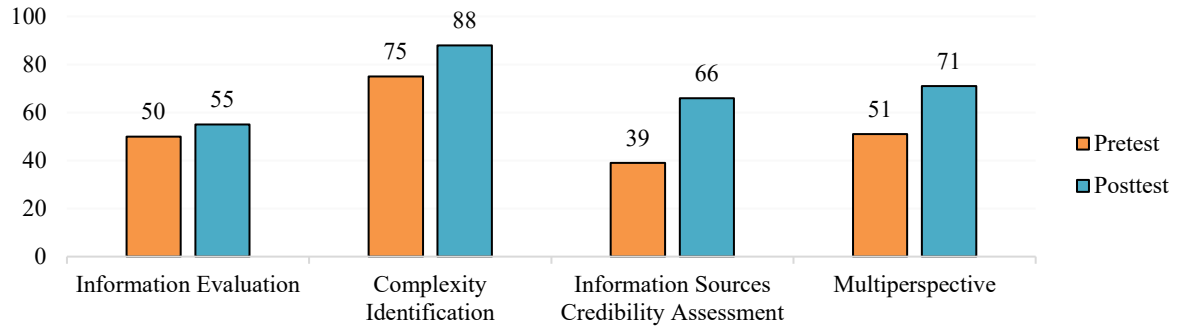


Figure 4. Profile of prospective natural sciences teachers' critical reasoning

The profiles of prospective natural sciences teachers' critical reasoning from the pretest and posttest, shown in Figure 4, indicate the multidimensional nature of the reasoning processes that have been successfully developed through the application of the place-based SSI approach. Within the place-based SSI approach, the dimensions of critical reasoning become particularly important because SSI often involves uncertainty and conflicting perspectives, indicating complex interactions between scientific evidence and existing sociocultural values. Improvements observed across each dimension of critical reasoning imply that the place-based SSI approach, when applied with a focus on issues related to the use of *kratom* and *tuak*—issues that are familiar to participants—creates a learning environment capable of supporting prospective natural sciences teachers in West Kalimantan to engage more deeply. This is supported by the findings of Herman et al. (2021), who found that the implementation of a place-based SSI approach has a positive impact on learning orientation and reasoning because it integrates personal experiences into the learning process and helps students recognize the interdependent relationship between nature and humans within the context of sustainable development. The SSI used in this study successfully prompted prospective natural sciences teachers to examine scientific claims more carefully while considering sociocultural standpoints, reinforcing the understanding that SSI must be approached through reasoning that draws on various perspectives to propose relevant solutions.

The pretest and posttest data were then used to assess the effectiveness of the place-based SSI approach in enhancing prospective natural sciences teachers' critical reasoning. Through the place-based SSI approach applied to the experimental and control groups, descriptive statistics were obtained and are presented in Table 4. The descriptive statistics reveal a positive trend in the experimental group that was exposed to instructional design using the place-based SSI approach. This finding is theoretically plausible because SSI-based learning places prospective teachers in situations where scientific evidence must be weighed against sociocultural standpoints (Lin et al., 2023; Namdar et al., 2025; Yahaya et al., 2015). Such situations, therefore, create opportunities for prospective natural sciences teachers to develop higher-order thinking skills-based competencies, which are rarely the focus of learning approaches based solely on knowledge acquisition. Given that the participants in this study were selected from classes with relatively comparable academic characteristics, it can be said that the differences observed in the posttest data across groups were the result of implementing the place-based SSI approach, rather than differences within each group that existed from the outset. Nevertheless, inferential statistics are used to determine whether the observed changes are statistically significant.

The normality of the pretest and posttest data was assessed using the Shapiro–Wilk test. The results indicate that the experimental and control groups follow a normal distribution, as their *p*-values exceed the 0.05 threshold (0.076 and 0.707, respectively). Furthermore, the homogeneity test using Levene's test showed that the variances of the two groups were homogeneous (*p*-value = 0.180, which is greater than the threshold of 0.05). The normality and homogeneity tests indicate that the data meet the prerequisites for proceeding to the t-test and effect size calculations using Cohen's *d*. The results of the t-test and effect size calculations for each dimension of critical reasoning are presented in Table 5.

Table 4. Descriptive statistics of the posttest data of each group

No.	Group	Participants	Mean ± Standard Deviation	Standard Error
1	Experimental	30	28.03 ± 5.417	0.989
2	Control	34	20.50 ± 4.481	0.768

Table 5. T-test and effect size of each critical reasoning dimension

No.	Dimension	*M*	*t*	*p*	Effect Size	Category
1	Information evaluation	-.16667	-1.634	0.113	0.31	Medium
2	Complexity identification	-.44444	-3.065	0.005	1.02	Large
3	Information sources credibility assessment	-.58889	-4.235	0.000	0.73	Medium
4	Multiperspective	-.66667	-4.916	0.000	0.67	Medium

The results of the t-test indicate that the place-based SSI approach positively contributes to the development of three out of four dimensions of critical reasoning among prospective natural sciences teachers, including complexity identification, information sources credibility assessment, and multiperspective, all of which showed significant improvements (p-value < 0.05). Among these three dimensions, complexity identification had the largest effect size, indicating that the intervention was particularly effective in enhancing prospective natural sciences teachers' ability to recognize the multifaceted nature of SSI in this study (i.e., the use of *kratom* and *tuak*). Complexity in SSI is identified through interrelated causal relationships, posing a challenge for teachers to possess the knowledge, skills, and attitudes necessary for a sufficient and systematic understanding when addressing SSI (Ke et al., 2023). Smit et al. (2026) noted a similar point, stating that SSI constitutes a system of relationships in the form of complex, ill-structured, and open-ended issues, thereby requiring strong capabilities to decipher its complexity.

The simultaneous enhancement of the dimension of information sources credibility assessment demonstrated an effect size classified as medium. These findings indicate that prospective natural sciences teachers became more discerning in evaluating the credibility of information found from various sources. The rapid rise of social media and the sharing of information require a critical approach to evaluating user-generated content for credibility and accuracy, as it is often not subject to rigorous scrutiny (Zhou, 2025). The multiperspective dimension also showed a medium effect size, suggesting that prospective natural sciences teachers are better able to consider diverse perspectives before reaching conclusions. This is supported by Cebesoy & Rundgren (2023), who argue that SSI-based learning that prioritizes multiple perspectives is crucial to encourage, as SSI incorporates various socioculturally grounded viewpoints, ultimately strengthening reasoning and decision-making in the development of prospective teachers' quality.

The information evaluation dimension contrasts with the other three dimensions of critical reasoning because it did not show a statistically significant increase (p-value > 0.05), despite a medium effect size. This finding is comparable to that of Yokhebed et al. (2024b), who also found that the information evaluation dimension in the application of the place-based SSI approach to senior high school students in West Kalimantan showed insignificant results despite having a medium effect size. The results obtained for this dimension indicate that instructional design with and without the place-based SSI approach does not exhibit specific distinctions in this dimension, assuming that prospective natural sciences teachers' ability to evaluate the quality of information and the strength of evidence may be more demanding than other dimensions; thus, strengthening this dimension requires a more complex process and more intensive scaffolding. In fact, the ability to evaluate information has become essential given the current flow of information, particularly for citizens who are deeply immersed in the high accessibility of information on the internet (Yokhebed et al., 2024a). Gill et al. (2026) explain that prompts for evaluating information in SSI systems can present various unique challenges influenced by prior experiences and knowledge, potentially hindering open-mindedness in evaluating relevant information.

Overall, the findings demonstrate that a place-based SSI approach can be an effective pedagogical practice for enhancing prospective natural sciences teachers' critical reasoning. The use of SSI in West Kalimantan, which includes the use of *kratom* and *tuak*—which to this day continue to spark debate—provides exceptional

contextuality and creates meaningful opportunities for prospective natural sciences teachers to connect with the realities of science and society in their communities and those around them. Therefore, a place-based SSI approach offers a promising framework for preparing prospective natural sciences teachers who can facilitate scientifically rigorous, socially relevant, and responsive learning in schools. By linking the findings of this study to the broader concept of place-based education, Jaikrasen & Ketsing (2025) note that the emphasis on place-based education within an authentic school context can enhance students' ability to appreciate and care for their surrounding environment, offering learning experiences grounded in sustainability. Moreover, Demirhan et al. (2026) state that teachers play an essential role in implementing place-based education, a concept with high educational value; therefore, it is important to understand how natural sciences teachers perceive the integration of locality and place-based education into classroom practices.

This study offers a novel contribution as the first to examine the application of a place-based SSI approach to enhance prospective natural sciences teachers' critical reasoning, focusing on the utilization of *kratom* and *tuak* as two local potentials in West Kalimantan, given that previous studies on SSI in West Kalimantan have been limited to other issues, such as illegal mining (Yokhebed et al., 2024a; Yokhebed et al., 2024b) and groundwater purification technology (Murdani et al., 2022). Beyond its immediate instructional outcomes, this study contributes to the development of science and society by providing empirical evidence that implementing a place-based SSI approach can enhance the critical reasoning of prospective natural sciences teachers. The findings of this study, therefore, expand the existing literature on SSI and strengthen the theoretical argument that a place-based SSI approach can enhance contextual relevance and foster deeper connections between prospective natural sciences teachers and the targeted scientific knowledge.

From a broader perspective, this study contributes to societal development by fostering scientifically literate citizens who can evaluate information and consider various stakeholder perspectives to make informed decisions about issues affecting the surrounding community. From a practical perspective, this study offers critical implications: teacher education programs must prepare prospective teachers to navigate an era marked by complex socioscientific challenges. The contributions of this study are highly relevant to achieving the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), which focuses on two targets. The first target is Target 4.7, which underscores the urgency of acquiring the knowledge and skills needed to promote sustainable development through responsible citizenship and respect for cultural diversity. Meanwhile, the second target is Target 4.c, which emphasizes the need to substantially increase the supply of quality teachers through effective teacher education programs.

CONCLUSION

The results indicate that the place-based SSI approach has positive impacts by enhancing prospective natural sciences teachers' critical reasoning. Analysis of the profile of prospective natural sciences teachers' critical reasoning, based on pretest and posttest data, shows a notable increase across all critical reasoning dimensions. Meanwhile, the inferential statistics utilized to assess the effectiveness of the place-based SSI approach showed a statistically significant improvement (p-value < 0.05) on the dimensions of complexity identification (effect size of 1.02, categorized as large), information sources credibility assessment (effect size of 0.73, categorized as medium), and multiperspective (effect size of 0.67, categorized as medium). However, the particular dimension of information evaluation was not significantly different, as indicated by a p-value of 0.113 (> 0.05), despite an effect size of 0.31 (medium). Overall, this study's results demonstrate that the place-based SSI approach, grounded in the specific contexts of *kratom* and *tuak*, is an effective pedagogical practice for enhancing prospective natural sciences teachers' critical reasoning. Future studies can explore effectiveness on larger, more diverse samples to improve the generalizability of the results. Furthermore, future studies can examine the effectiveness of the place-based SSI approach in other contexts by using various other SSI in West Kalimantan, such as peatland management, deforestation, and mangrove conservation.

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AUTHOR CONTRIBUTION STATEMENT

Y: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, and writing – original draft. MAF: conceptualization, formal analysis, methodology, resources, visualization, and writing – original draft. EA: formal analysis, methodology, software, visualization, and writing – original draft. RM: data curation, formal analysis, investigation, methodology, and writing – original draft. EO: writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the study, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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