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Critical thinking skills of prospective chemistry teachers in chemistry learning with Ethno-Socio-Scientific issues integrated inquiry

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Abstract

This study aims to develop a valid and practical Ethno-SSI integrated inquiry strategy to improve the critical thinking skills of prospective chemistry teachers. The research method used is Plomp's research and development model, with a convenience sampling technique obtained from a sample of 52 prospective chemistry education teachers at one of the universities in Indonesia. Data was collected through observation, a critical thinking test, and a questionnaire. Data analysis was carried out qualitatively and quantitatively. The results of strategy development obtained a new syntax called OETACA (orientation, exploration, transformation, argumentation, conclusion, and application) with a content validity score of 0.83 and construct 0.93. The results of improving critical thinking skills on a small scale get an N-Gain score of 0.7 in the high category supported by the perceptions of prospective chemistry teachers who strongly agree (43%) and agree (41%) to implement the Ethno-SSI integrated inquiry strategy in chemistry learning in the classroom.

Article History

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1. critical thinking skills;
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Highlights

- Ethno-SSI is a combination of ethnoscience and Socioscientific Issues.
- Religion, environment, culture, health, and society.
- Orientation, exploration, transformation, argumentation, conclusion, application.
- Thermochemical material in the context of burning snail satay.
- Controversial, dilemmatic, and complex issues.

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1. Introduction

The development of education in the 21st century requires students to have a strong understanding of content areas such as math, language, and science (Boholano, 2017; Council, 2012), and also to various skills such as critical thinking, problem-solving, communication, collaboration, and curiosity (Tan *et al.*, 2017; Wahono *et al*., 2021). These skills are needed to face future global challenges (Lee *et al*., 2012). Innovation in education is required so that the educational process is in line with the circumstances and needs of prospective chemistry teachers in the 21st century. Therefore, educational practices that were initially only in the form of transferring knowledge from lecturers to students are no longer effectively used to prepare young people who will be competent in the 21st century: student-centered learning that will provide opportunities for students to develop their interests and talents (Boholano, 2017); learning that develops the ability to gather information from all sources so that there is a long-life learning process (Lee *et al*., 2012); the use of Information and Communication Technology (ICT) and various virtual devices provides flexibility to find quality learning resources (Dewi *et al*., 2019); emphasizing hands-on learning (Fuad *et al*., 2017); developing soft skills of critical thinking, creativity, problem-solving, collaboration, and social interaction (Rahayu, 2017); and providing flexibility in the learning process (Hussin, 2018).

Critical thinking skills are part of High Order Thinking Skills (HOTS), one of the skills needed and needs to be continuously trained so prospective chemistry teachers can survive in the 21st century (Barak and Dori, 2009; Tajudin and Chinnappan, 2016). Choi *et al*., (2011) research results show that one of the aspects developed in the dimensions of science literacy in the habitual thinking domain is critical thinking skills. This skill is the basis for solving challenging problems in the 21st century that occur in a global society (Boholano, 2017). Ennis (1990) mentions that critical thinking aims to decide what to believe or do reasonably, using reasoning and logic in thinking and learning the truth based on specific thinking patterns (Ennis, 2011a). A different definition is given by Facione (2011), who states that critical thinking is a mind that aims to prove a point/opinion, interpret something meaningful, and solve problems (Facione, 2011). Although several theories and educators have developed definitions and conceptualizations of critical thinking, studies on factors influencing critical thinking skills still need to be completed (Kwan and Wong, 2015), especially in chemistry learning.

Prospective chemistry teachers must be able to understand the characteristics of chemistry, namely being able to explain phenomena macroscopically, submicroscopically, and symbolically; investigate the dynamics of processes and energy changes during chemical reactions by conducting investigations; and explain chemical processes in life (Suwahyu and Rahayu, 2023). Prospective chemistry teachers instil in themselves that chemistry is essential, that chemistry exists in life, and that all life processes have chemistry so that when they graduate, they can provide understanding directly to the community (Putri *et al*., 2022). In addition, chemistry is full of sometimes confusing language terminology, so it is necessary to introduce scientific language to prospective chemistry teachers so that they can use chemical languages correctly (Bechtel, 2016).

Chemistry learning has rarely been given issues that prospective teachers can debate, such as socioscientific issues (Rahayu *et al*., 2020). The case of socioscientific problems is characterized by controversial contemporary issues; ethical, moral, and dilemmatic elements raise debate and the need to make decisions in solving SSI problems (Sadler and Zeidler, 2005; Zeidler *et al*., 2019). SSI cases can be used to dialogue, discuss, and debate, among the characteristics of science-literate people (Barrue and Albe, 2013; Herman *et al*., 2019; Leung, 2022). These SSI cases are essential in chemistry education because they can be used as more relevant science learning in life, improving learning outcomes, argumentation skills, scientific information, critical thinking, and other essential aspects supporting science literacy (Borgerding and Dagistan, 2018; Chen and Xiao, 2021; Fadly *et al*., 2022; Presley *et al*., 2013; Rahayu, 2019). SSI can train critical thinking skills because it involves social-scientific, moral, and ethical issues, and considers various different perspectives in decision-making (Genel and Topçu, 2016; Herman *et al*., 2021; Sadler and Donnelly, 2006; Zeidler *et al*., 2009). In the context of SSI, prospective chemistry teachers are trained to think critically by being confronted with global and contextual problems that require them to analyze data, evaluate, and draw logical conclusions based on scientific evidence (Eastwood *et al*., 2012; Herman *et al*., 2019; Rahayu, 2021).

Several research results show that the critical thinking skills of prospective chemistry teachers are still low (Hunnicutt *et al*., 2015; Mitarlis *et al*., 2020). Based on observations of early semester students in one of the universities in Indonesia, many problems need to be solved to enhance students' critical thinking and chemical literacy. This can be seen from the low understanding of student concepts; students need help based on existing evidence, facts, and theories when being given questions on chemical topics. Then, students need to be able to design scientific inquiry activities by using correct procedures before carrying out practicum activities. Furthermore, interest in chemistry and students' level of awareness in responding to current chemistry-related issues still need to be improved (Sulistina *et al*., 2021). Communication skills such as dialogue, discussion, and debate are rarely implemented in class so students become passive in learning chemistry and their critical thinking skills become low (Winarti *et al*., 2024). Students currently acquire knowledge only based on what is given by the lecturer, not looking for themselves from various other sources relevant to the material being taught, so their concept knowledge and their perception toward meaningful topic in daily life is still low (Wiyarsi *et al*., 2021).

Several studies have been done to improve the critical thinking skills of prospective chemistry teachers using various models and approaches but some of the results are not optimal (Abdurrahman *et al*., 2020; Aiman *et al*., 2020; Cahyarini *et al*., 2016; Sutiani *et al*., 2021; Zidny *et al*., 2020). There was no significant difference between the critical thinking skills of prospective chemistry teachers in the control class and the experimental class with the inquiry model (Qing *et al*., 2010). Furthermore, the Scientific Critical Thinking (SCT) of prospective chemistry teachers can be improved with the inquiry-PBL model, but the results are not optimal (Yuanita *et al*., 2019). Irwanto *et al*., (2019) used POGIL, but the results were still insignificant in improving prospective chemistry teachers' critical thinking and problem-solving skills. Prospective chemistry teachers' science process and critical thinking skills were still low due to a lack of experience in inquiry-based laboratories (Irwanto *et al*., 2019). ABI (Argument-based inquiry) affected the critical thinking skills of prospective chemistry teachers but had limitations, namely the need to conduct a more detailed analysis of indicators and trends in critical thinking skills (Sönmez *et al*., 2019). The three-level inquiry-based chemistry learning given to prospective teachers did not significantly improve critical thinking skills (Muskita *et al*., 2020). The critical thinking skills of students taught with the inquiry learning model were not strong enough, generally at the medium and low levels. Based on the results of various studies

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above, it can be concluded that many studies use inquiry to improve critical thinking skills, although the results are less than optimal (Arsal, 2017). This is because this inquiry model focuses on active student participation, the ability to ask scientific questions, and student involvement in investigations to find answers to scientific questions to improve their critical thinking skills (Council, 2018; Goldkuhl, 2008). Theoretically, the weaknesses of the various inquiry models above can be overcome by improvements or innovations in strategies, approaches, and steps so that the results of these improvements will be able to improve the critical thinking skills of prospective chemistry teachers by using the context of local wisdom and SSI.

Currently, the complexity of SSI in the context of local wisdom has been studied by several researchers worldwide in the fields of environment, health, socio-politics, and socio-culture. SSI problems in the environmental field include biofuels (Dauer *et al.*, 2021; Nida *et al.*, 2021a), nuclear power plants (Jho *et al.*, 2014; Wang *et al.*, 2018; Yuenyong, 2013), water pollution (Ladachart and Ladachart, 2021; Owens *et al.*, 2022), air pollution (Herman *et al.*, 2021), and global warming (Nida *et al.*, 2021b). In the health sector, they include Genetically Modified Food (GMO) (Lederman *et al.*, 2014), unslaughtered animals, synthetic food, artificial meat (Adal and Cakiroglu, 2022), uterine borrowing (Raveendran, 2021), malnutrition, toxicity (Waard *et al.*, 2020), cloning, abortion, and HIV-positive children (Bencze *et al.*, 2020). Local wisdom-based SSI in the socio-political field includes cases of discrimination, racism, colonialism, social justice power in South Africa (Diwu and Ogunniyi, 2013), waste-to-energy plants (Dawson and Carson, 2020), animal welfare issues, and whale killing methods (Grace *et al.*, 2015). Meanwhile, local wisdom-based SSI in the socio-cultural field includes traditional rituals (Mavuru and Ramnarain, 2020), myths (Canel-Çınarbaş and Yohani, 2019), gender differences, social norms, religion, and beliefs (Raveendran, 2021; Wahono *et al.*, 2021). Some of these research problems have not taken the context of controversial regional culinary specialities and traditional herbs, so researchers are interested in developing this research. Ethno-SSI is a combination of ethnoscience and Socioscientific Issues.

The SSI approach in the context of local wisdom has developed many research variables on critical thinking skills (Nida *et al.*, 2021b; Raveendran, 2021; Yacoubian, 2020; Zidny and Eilks, 2022). Critical thinking skills are one of the higher-order thinking skills (HOTS) whose activities include analyzing, evaluating, and reasoning (Ennis, 2011b; 2013). This ability is essential to develop the potential possessed by prospective chemistry teachers to analyze and solve SSI problems within the context of local wisdom. Prospective chemistry teachers with critical thinking have opened their minds to formulate problems correctly, collect information appropriately and relevantly, interpret ideas, make conclusions accompanied by reasons, communicate effectively, and find solutions to complex problems (Ennis, 2011b; Kölbel and Jentges, 2018; Masni *et al.*, 2020). Research questions:

1. How to develop a valid and practical Ethno-SSI integrated inquiry strategy?
2. What are the results of critical thinking skills of prospective chemistry teachers using the Ethno-SSI integrated inquiry strategy?
3. What is the perception of prospective chemistry teachers using the Ethno-SSI integrated inquiry strategy?

2. Method

2.1. Research design

The method used in this research is Research and Development. This research produces a product in the form of an Ethno-SSI integrated inquiry strategy to improve the critical thinking skills of prospective chemistry teachers using Plomp's model. Plomp's development model in this study consists of three stages shown in **Fig. 1**, namely (1) preliminary research (initial investigation with needs analysis and problem identification); (2) Development or Prototyping phase Initially (development and implementation of prototypes/products); (3) Assessment phase (assessment and evaluation) (Plomp *et al.*, 2013).

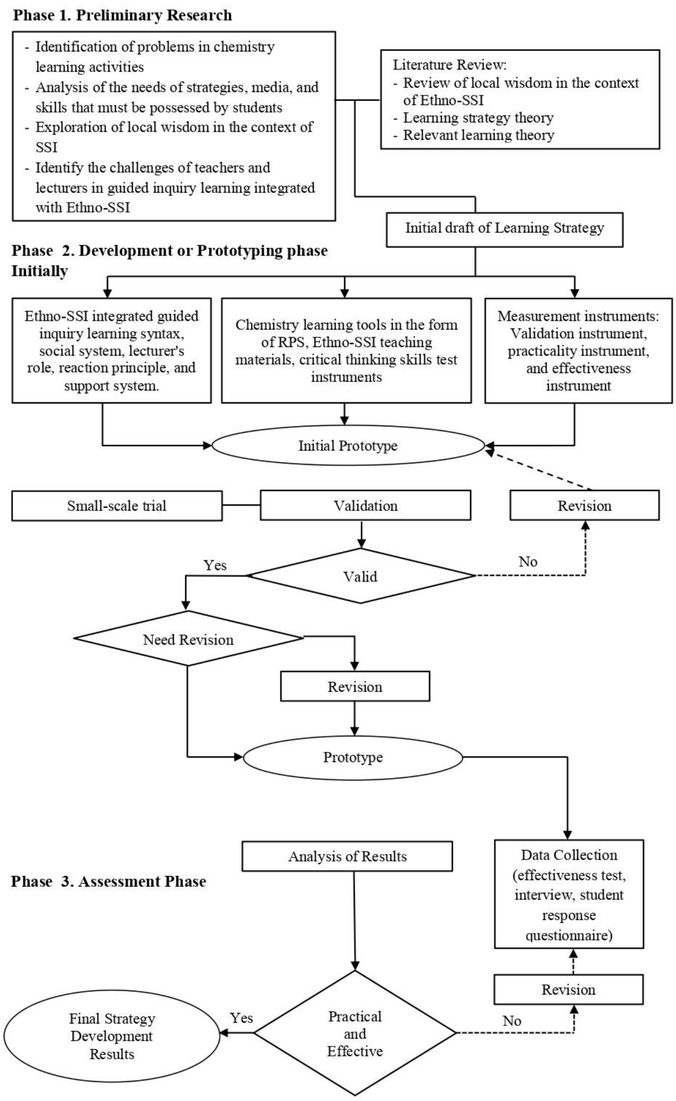

Figure 1. Flow of Research and Development learning strategy according to Plomp *et al.* (2013) model.

2.1.1. Preliminary research

Activities at this stage aim to explore initial data or information in developing learning strategies. Activities carried out in preliminary research include: (1) Identifying various problems related to the context of Ethno-Socioscientific Issues in Essential Chemistry Learning. The problems studied must contain elements of local wisdom that are controversial and dilemmatic in society

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regarding health, religion, culture, society, and the environment. This supports orientation activities consisting of problem identification and problem formulation used in learning strategies; (2) Reviewing learning theories that become the foundation in developing inquiry learning strategies based on Ethno-Socioscientific Issues; (3) Analyze the requirements for developing learning strategies, such as suitability to the curriculum, student conditions, number of lesson hours, learning environment, and field conditions for direct exploration activities; and (4) Formulate a rationale for the importance of developing an inquiry strategy integrated with Ethno-Socioscientific Issues to improve the critical thinking skills of prospective chemistry teachers.

2.1.2. Prototyping phase or prototype development

At this stage, activities are advanced from problem identification in preliminary research to designing problem-solving. In solving the problem, the teacher must divide the activities into coherent stages so that they become a unified whole. The solution to the problem developed in this study resulted in a prototype design that was implemented in the form of: (1) an academic manuscript or book of inquiry strategy based on Ethno-Socioscientific Issues; and (2) Learning tools or instruments consisting of RPS (Semester Lecture Plan), Ethno-SSI Context Basic Chemistry students worksheet, PPT, teaching materials and learning videos, and assessment instruments (critical thinking skills test questions). The developed product or prototype is then re-examined for the completeness of each component and then tested for validity by expert validators.

2.1.3. Assessment phase

Activities at this stage aim to assess the draft strategy that has been developed. The results of this assessment and consideration will lead to a decision on the next step. The activities at this stage are as follows: (1) Conduct validation related to the prototype designed and developed by expert validators; (2) The assessment results from the validator are then continued by making improvements based on suggestions, criticisms, and input from expert validators; and (3) Collecting, processing, and analyzing data from assessing critical thinking skills by applying the developed Ethno-Socioscientific Issues-based inquiry strategy. Phases of research and development according to Plomp *et al.* (2013) model Shown in **Fig. 2**.

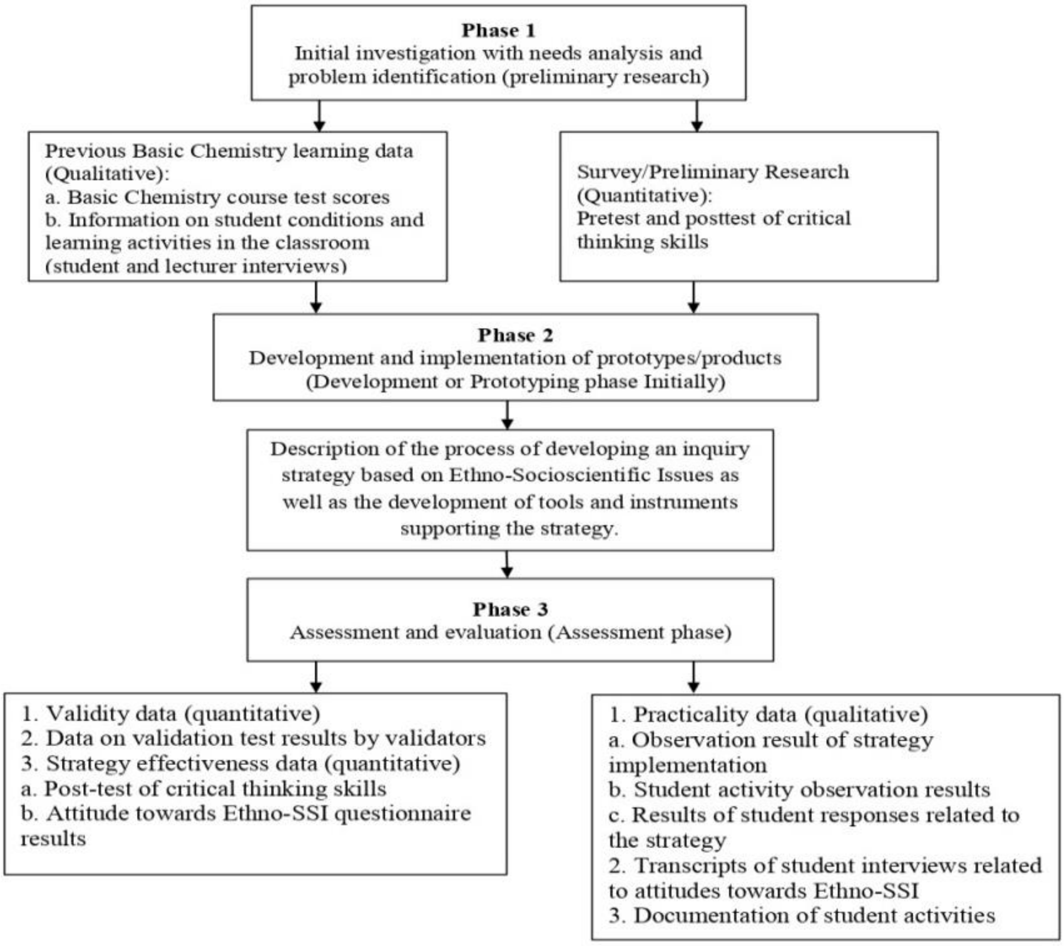

Figure 2. Phases of research and development according to Plomp *et al.* (2013) model.

2.2. Sample

This research involved one of the state universities in East Java, Indonesia, and took place from August to October 2023. The activity began with exploring Ethno-SSI in Central Java and East Java to be used as a context in chemistry learning. Sampling was conducted during the small-scale trial using the convenience method. The research sample consisted of prospective chemistry teachers (N=52) who taking basic chemistry courses in their first semester. The Basic Chemistry course in this study uses the 2023 department curriculum, learning using guided inquiry, which includes theory and practice in the laboratory. Learning was

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conducted for five meetings on Thermochemistry (three meetings in class learning material, one exploration activity in the community, and one practicum activity in the chemistry laboratory).

2.3. Data collection

Qualitative data collection (RQ1) was obtained from validation and observation sheets of classroom learning implementation activities and expert validation. Expert validation data in the form of criticisms, suggestions, and opinions about the developed strategy. Quantitative data collection (RQ2) was conducted with a critical thinking test. Meanwhile, qualitative data collection (RQ3) was conducted through questionnaires.

2.4. Test instrument development (RQ2)

Test instrument development uses the stages (Define, Design, Develop) developed by Thiagarajan and Ennis' critical thinking skills framework, which consists of elementary clarification, basic support, interference, advanced clarification, and strategy and tactics.

Define: First, analyse the characteristics of prospective chemistry teachers in accordance with the design of developing basic chemistry question instruments integrated with Ethno-SSI to achieve critical thinking skills. Second, develop question instruments based on a concept analysis literature review to identify material that can be integrated with ethno-SSI. Third, indicators of critical thinking skills on the questions should be identified.

Design: The second stage was designed by constructing items based on critical thinking skills indicators (elementary clarification, basic support, interference, advanced clarification, and strategy and tactics). Furthermore, we describe each indicator of essential skills of thinking, design questions, and assessment rubrics (question and answer grids), followed by writing items using Indonesian.

Develop: The third stage was to develop test instruments that experts validated. Experts were asked to review each question item based on the following criteria: (a) substance and indicators of critical thinking skills to be achieved; (b) clarity of question items in words/phrases/pictures/tables; (c) use of correct Indonesian grammar; and (d) completeness of the question instrument. The test instrument's validation results received comments/feedback and were then revised to improve the items.

Three people carried out material expert validation to evaluate the validity of the product of the Ethno-SSI context critical thinking question instrument. The validation findings produce constructive criticism and suggestions to improve the developed question instrument, which will be evaluated in small groups and field trials. During the validation process, qualitative and quantitative data will be collected. Qualitative data consists of suggestions, criticisms, responses, and input derived from validator comments. Quantitative data consists of assessment data collected through a questionnaire developed by the researcher. The completed questionnaire uses a scoring system adjusted to the criteria given on the form, using a 4-level Likert scale shown in **Table 1**.

Table 1. Criteria for validator answer levels.

Score	Description
4	good / worthy / interesting / clear / appropriate
3	quite good / quite feasible / enough
2	Interesting / clear enough / precise enough / appropriate
1	less good / less feasible / less interesting / unclear / less precise / less appropriate

The assessment results from the validators were then analysed using the CVI statistical technique. CVI is divided into two types of validation, namely (i-CVI) or the validity of the content of individual items, and (s-CVI) or the validity of the content of the items as a whole Lynn, (1986). The CVI calculation method starts with the scores obtained from each validator, which are converted into dichotomous values of 0 and 1 to be analysed with CVI. The way to convert the scale is that scores 1 and 2 are included in dichotomy 0, which means they are not feasible, while scores 3 and 4 are included in dichotomy 1 with the feasible category. Furthermore, from the three validators, the average of each item is determined or called i-CVI, and the average of i-CVI is the s-CVI value. The criteria for determining the validation results in this study refer to Guilford and Fruchter (1978) which consists of:

0.80 < Mean-CVI < 1.00 = excellent (very high validity)
0.60 < Mean-CVI < 0.80 = good (high validity)
0.40 < Mean-CVI < 0.60 = fair (medium validity)
0.20 < Mean-CVI < 0.40 = poor (very low validity)
Mean I-CVI < 0.00 = invalid

The practicality test categories of the Ethno-SSI integrated inquiry strategy in this study consist of:

81–100% = very practical
61–80% = practical
41–60% = moderate
21–40% = less practical
0–20% = not practical

Feedback, suggestions, and input from validators are used to assess the quality, relevance, and effectiveness of questions made questions that experts from chemistry education have validated. It can also increase the acceptability or acceptance of instruments because it has undergone a rigorous evaluation process. The results of the validity of the critical thinking test and questionnaire instruments assessed by three experts with the Content Validity Index (CVI) score are shown in **Table 2**.

The data in **Table 2** shows that the results of material expert validation on critical thinking skills instruments and questionnaires get high scores. The SCI-Ave score on basic chemistry questions in the Ethno-SSI context is 0.904, and S-CVI/UA receives a score of 0.714, which means the question is acceptable, relevant, and valid. Validator input and evaluation are expected to improve the instrument made. According to Dwianto *et al*. (2017), test instruments are considered feasible and suitable if there is a match between the questions and the topic, and the abilities being assessed. The test instrument is considered adequate if it fulfills all the criteria for evaluating the instrument and it can improve the critical thinking skills of prospective chemistry teachers. This study shows that the questions made have successfully fulfilled all critical thinking skills test criteria so that they can be used for small-scale trials. The results of suggestions for improvement from the material validator are shown in **Table 3**.

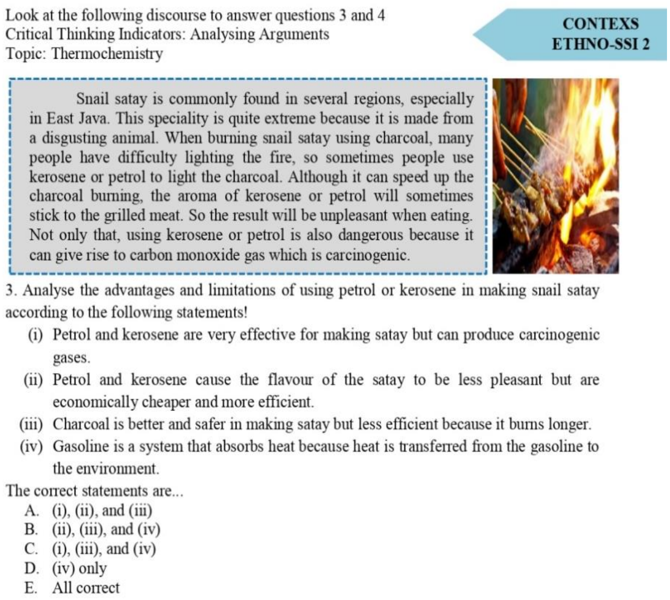
After being validated, the next step was to test critical thinking skills questions conducted on prospective chemistry teachers at one of the universities in Indonesia (N = 57) with a total of 30 multiple-choice questions. The trial of questions was carried out to check the level of difficulty of the items, construct validity, and reliability. The results of the reliability of chemical literacy items scored 0.93, indicating high reliability. An example of a critical thinking skills test instrument for the topic of Thermochemistry is shown in **Fig. 3**.

Table 2. Content validity index of research instruments.

Instrument	S-CVI/Ave	Category	S-CVI/UA	Category
Critical Thinking Test	0.904	High	0.714	Accept/relevant/valid
Questionnaire	0.890	High	0.875	Accept/relevant/valid

Table 3. Suggestions for improvement critical thinking skills test.

Category	Suggestions for Improvement
Relevance of material	- Ensure the questions are directly related to thermochemical concepts, such as enthalpy, phase change, and the laws of thermodynamics. - The questions made are relevant, but the relationship between the chemical concept and the local culture discussed needs to be strengthened.
Critical thinking skills	- Questions should encourage prospective chemistry teachers to analyze and evaluate information, not just remember the material. - The chemical concept used in the questions is correct, but it is necessary to review it again for critical thinking questions, it would be better in the form of analysis rather than calculation.
Ethno-SSI context	Include indicators of critical thinking skills in each question. the Ethno-SSI discourse discussed in the questions is quite complex, but questions can be added to compare traditional and scientific methods.
Clarity and readability	Integrate the ethno-SSI context in the questions to increase their relevance and connection to prospective chemistry teachers' daily lives.
Language, images, tables	- Ensure the language in the questions is easy to understand, avoid unfamiliar technical terms, and use EYD and appropriate chemical formulas. - The images and tables are already there, but it is necessary to clarify the illustrations in the images/tables containing the information asked in the questions.


Look at the following discourse to answer questions 3 and 4
Critical Thinking Indicators: Analysing Arguments
Topic: Thermochemistry

CONTEXS ETHNO-SSI 2

Snail satay is commonly found in several regions, especially in East Java. This speciality is quite extreme because it is made from a disgusting animal. When burning snail satay using charcoal, many people have difficulty lighting the fire, so sometimes people use kerosene or petrol to light the charcoal. Although it can speed up the charcoal burning, the aroma of kerosene or petrol will sometimes stick to the grilled meat. So the result will be unpleasant when eating. Not only that, using kerosene or petrol is also dangerous because it can give rise to carbon monoxide gas which is carcinogenic.

3. Analyse the advantages and limitations of using petrol or kerosene in making snail satay according to the following statements!
(i) Petrol and kerosene are very effective for making satay but can produce carcinogenic gases.
(ii) Petrol and kerosene cause the flavour of the satay to be less pleasant but are economically cheaper and more efficient.
(iii) Charcoal is better and safer in making satay but less efficient because it burns longer.
(iv) Gasoline is a system that absorbs heat because heat is transferred from the gasoline to the environment.

The correct statements are...
A. (i), (ii), and (iii)
B. (ii), (iii), and (iv)
C. (i), (iii), and (iv)
D. (iv) only
E. All correct

Figure 3. Critical thinking test question example based Ethno-SSI.

2.5. Data analysis

The data analysis in this study is shown in **Table 4**.

The field trial results in the first stage (small scale) conducted in this study were used to improve the Basic Chemistry strategy and instruments with the Ethno-SSI context, which aims to improve critical thinking skills. These results were then analysed and revised to improve and will be used on a wide scale or effectiveness test.

To answer RQ 1, the data were analysed descriptively and qualitatively, explaining the development of the Ethno-SSI integrated inquiry strategy and input from validators. Data analysis used to answer RQ 2 is quantitative N-Gain supported by descriptive study to describe the critical thinking skills of prospective chemistry teachers. Students' answers were grouped based on the rubric for assessing critical thinking skills indicators developed by Ennis (1993) and then processed as a percentage.

$$\text{Critical thinking skills score} = \frac{\textit{Number of correct answers}}{\textit{Maximum score}} \text{x } 100$$

According to **Table 5**, the percentage value is then interpreted as being in the very high, high, medium, low, and very low categories and Ethno-SSI critical thinking skills indicators is shown in **Table 6**.

Table 4. Research questions and tools of the research.

Research Questions	Tools	Data Analysis
RQ1: How is the development of the Ethno-SSI integrated inquiry strategy?	- Literature review - Validation sheet - Observation sheet	Descritive qualitative
RQ2: How the results of the critical thinking skills of prospective chemistry teachers using the Ethno-SSI integrated inquiry strategy in small scale?	Chemical literacy test	Quantitative, N-gain
RQ3: How the perception of prospective chemistry teachers using the Ethno-SSI integrated inquiry strategy?	Open-ended questionnaire	Descritive qualitative

Table 5. Category and criteria critical thinking skills.

Category	Score	Criteria
Very Low	0-20	Prospective chemistry teachers are only able to understand basic information without being able to make analysis and evaluation, and their arguments are very limited.
Low	21-40	Prospective chemistry teachers can make simple arguments but still have thinking errors and are less capable of deeper analysis and evaluation.
Medium	41-60	Prospective chemistry teachers can analyze and make evaluations at a sufficient level. In addition, the arguments made are also more complex, although they still show weaknesses in several aspects.
High	61-80	Prospective chemistry teachers have good critical thinking skills by recognizing, analyzing, and evaluating arguments more effectively, structured, and logically.
Very High	81-100	Prospective chemistry teachers have high critical thinking skills by being able to solve complex problems, analyze in depth, and evaluate arguments logically and cohesively.

Source: Elaborated by the author using data from Ennis (1993).

Table 6. Ethno-SSI critical thinking skills indicators.

No	Indicators	Critical thinking skills integrated Ethno-SSI
1	Elementary Clarification	Focusing on questions, analyzing questions, and asking and answering questions about a local wisdom Ethno-SSI phenomenon.
2	Basic Support	Establish the credibility of a source, scrutinize and assess the results of Ethno-SSI explorations and investigations.
3	Interference	Reduce and assess deduction, induce and assess induction, and determine the results of moral, ethical, and religious considerations in the context of Ethno-SSI.
4	Advanced Clarification	Define terms, assess definitions, and identify problematic assumptions of Ethno-SSI cases.
5	Strategy and Tactics	Decide on a course of action and interact with others to resolve Ethno-SSI cases using inquiry strategies.

As for RQ 3, students' perceptions were analysed descriptively qualitatively based on the results of a questionnaire that focused on (1) the relevance of Ethno-SSI in chemistry learning, (2) interest in the Ethno-SSI integrated inquiry strategy, and (3) improving critical thinking skills. The questionnaire in this study consisted of 10 items with scoring using a five-point Likert scale. The answers were strongly agree (score=5), agree (score=4), neutral (score=3), disagree (score=2) and strongly disagree (score=1).

2.6. Ethical clearance of research

This research obtained a research permit from the dean of the Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang No. 22.9.69/UN32.3.1/TU/2023 so that it can be ascertained that the data collection in this study has complied with the law and was carried out legally. This research also fulfils ethical feasibility based on the ethical feasibility certificate No. 14.6.7/UN32.14/PB/2024.

3. Results and discussion

3.1. Development of valid and practical Ethno-SSI integrated inquiry strategies

The results of content validity show the suitability of the strategy with supporting theories and learning outcomes, while the results of construct validity show the suitability of the syntax and complementary strategies developed with learning theory and empirical evidence, as shown in Table 7.

Table 7. Content validity and construct validity of Ethno-SSI integrated inquiry strategy.

Aspect	S-CVI/Ave	Category	S-CVI/UA	Category
Content validity	0.83	Medium	0.50	Accept/relevant/valid
Construct validity	0.90	High	0.71	Accept/relevant/valid

The results of content validation and construct validation conducted by experts on the academic manuscript of the Ethno-SSI integrated inquiry learning strategy resulted in an average score of 3.50 out of 4.00, which indicates that the prototype of the Ethno-SSI integrated inquiry learning strategy is declared appropriate, valid, and feasible to use with revision. Based on the results of the CVI (Content Validity Index) analysis in Table 7. content validity obtained a CVI score of 0.83 and construct validity of 0.90 with a high category so that the Ethno-SSI integrated inquiry strategy can be accepted and continued for research in improving the critical thinking skills of prospective chemistry teachers but with some improvements/revisions from the validator. Suggestions from validators include: 1) the concept of chemistry material with the Ethno-SSI context needs to be explained in more detail and contextually; 2) the rationality of the strategy needs to be considered from the novelty, supporting theory, and weaknesses of previous research; 3) improvements in content preparation starting from rationality, strategy development, and its application in chemistry learning need to be improved.

The validity results are supported by the practicality of the Ethno-SSI integrated inquiry strategy obtained from the observation sheet. The results of observations on implementing the Ethno-SSI integrated inquiry strategy were carried out through observations by two observers, as shown in **Table 8**.

Table 8. Learning observation.

Meeting (material)	Average Applicability		Average	Applicability (%)	Category
	Observer 1	Observer 2			
1-5 Thermochemistry	3.50	3.40	3.45	86.25	very practical

Table 8 shows that the average implementation of learning activities is 86.25%, which means that the implementation of the inquiry integrated Ethno-SSI syntax OETACA is categorized as very practical. Obstacles during learning become notes for improvement in the development of Ethno-SSI integrated inquiry strategy with OETACA syntax. The data from observing and obstacles found during the learning process using the OETACA syntax are processed and analyzed, and conclusions are drawn to complement a small-scale trial and improvements for large-scale effectiveness testing.

Based on the results of various learning models, an inquiry was one of the effective models for improving prospective chemistry teachers' critical thinking skills. Findings from the literature review results and data analysis show that the inquiry learning model can solve SSI cases (Chadwick *et al.*, 2023; Genel and Topçu, 2016; Saija *et al.*, 2022), and it is considered appropriate to apply the Ethnoscience approach (Alim *et al.*, 2020; Okechukwu *et al.*, 2014; Zidny *et al.*, 2020). The inquiry developed in this study is a modification of the 5E inquiry model (Engage, Explore, Explain, Elaborate, Evaluate) according to Bybee (2015). This model was chosen because it does not only focus on mastering material content but can also develop skills such as critical thinking, creativity, communication, and collaboration, which are the demands of 21st-century skills (Boholano, 2017; Masni *et al*, 2020; Syahrial *et al.*, 2021), so that prospective chemistry teachers are ready to face global challenges. In addition, the ethnoscience approach and socioscientific issues provide a relevant context in everyday life (Hofstein *et al.*, 2011; Ke *et al.*, 2021; Yazidi and Rijal, 2024), so that students can connect their knowledge through scientific, social, and cultural contexts according to Bybee (2015) stages. Through the exploration stage, prospective chemistry teachers can find and develop solutions to social scientific issues by analysing situations, considering various perspectives, and formulating sustainable solutions (Duschl and Bybee, 2014; Puig and Evagorou, 2020).

Bybee (2015) inquiry has weaknesses when applied to the context of Ethno-Socioscientific issues, including ethnoscience and SSI approaches involve many perspectives and complex research variables, so prospective chemistry teachers can have difficulty in understanding chemistry concepts in the Ethno-SSI context. This inquiry also has not placed the aspect of reconstruction or transformation, which is an important aspect of the ethnoscientific approach. Modifying the 5E inquiry steps (Engage, Explore, Explain, Elaborate, Evaluate) Bybee, (2015) The theoretical review and needs analysis results formed a new syntax with the term OETACA (Orientation, Exploration, Transformation, Argumentation, Conclution, Applications). The learning process with OETACA syntax, as shown in **Table 9**, aims to improve the critical thinking skills of prospective chemistry teachers. The conceptual framework of inquiry integrated Ethno-SSI syntax OETACA with critical thinking skills is shown in **Fig. 4**.

Table 9. The learning process of Ethno-SSI integrated inquiry syntax OETACA with critical thinking skills indicators.

Phase (modification)	Learning Objectives	Learning Process	Critical thinking skills indicators
Orientation (Engage phase)	Chemistry teacher candidates actively engage in the process of discovery and scientific inquiry by analyzing ethno-SSI cases involving health, religious, cultural, environmental, and social aspects.	- Listen to the lecturer's explanation regarding the topic and learning objectives of thermochemistry, which will be discussed in the context of ethno-SSI burning snail satay. - Listen to the apperception of ethno-SSI integrated chemistry material, both from the discourse in the student worksheets and also the video of the ethno-SSI problem of burning snail satay in the news. - Divide the discussion group. - Identify ethno-SSI problems with burning snail satay from the perspectives of health, religion, culture, environment, and society. - Formulate problems appropriately on the thermochemical material discussed according to Ethno-SSI of burning snail satay.	Basic clarification
Exploration (Exploration phase)	Solve problems by interacting with their environment so prospective chemistry teachers can gain experience and find new knowledge from Ethno-SSI exploration activities.	- Explore the Ethno-SSI case of burning snail skewers on producers. - Make data collection instruments by making interview guidelines and observation sheets. - Collect data by conducting observations, interviews, and documentation related to the making and burning of snail satay. - Record the results of the exploration on the student worksheets provided. - Provide a checklist (√) for interview data that can be transformed into scientific knowledge. - Search for references that support the Ethno-SSI of burning snail satay from several sources, including books, scientific journal articles, news in mass media/online, or other sources relevant to the topic as a reference in scientific transformation activities.	Basic support
Transformation (Reconstruction)	Can connect indigenous knowledge to scientific knowledge.	- Reconstruct the original knowledge of the community into scientific understanding from the references obtained. - Design Ethno-SSI practicum/project activities for charcoal making and thermochemical tests from exploratory studies.	Advanced clarification

		– Record the Ethno-SSI practicum/project data results on the student worksheets provided. – Paste evidence of exploration/observation/interview results on the student worksheets provided. – Transfer the transformable interview data into the transformation table.	
Argumentation **(Explain and elaborate)**	Knowledge does not only exist in an individual's mind but also through a reconstruction process by considering relevant sources, laboratory activities, and the surrounding physical, cultural, and social environment.	– Discuss in groups to solve/answer questions about the Ethno-SSI context of burning snail skewers in scientific arguments. – Answer scientific arguments about burning snail skewers with claims, evidence, and explanations. – Direct students in arguing through dialogue, discussion, and debate, and then making the right decision. – Determine whether the issue is true/false, good/no, agree/disagree. – Provide supporting evidence for claims in the form of data obtained during experiments/practicums and data obtained from the results of scientific transformations. – Make explanations in statements to support evidence, namely the reasons for claims based on applicable theories, laws, or principles.	Advanced clarification
Conclusion **(Evaluate)**	Train opinion, dialogue, discussion, debate, and make decisions by finding data and facts to solve problems based on claims, evidence, and explanations.	– Make conclusions based on the results of exploration, transformation/experimentation, data analysis, and scientific argumentation. – Make decisions about chemical problems in the Ethno-SSI context of burning snail satay. – Listen to the lecturer clarify the correct answers and conclusions based on the chemical material of the ethno-SSI context of burning snail satay discussed.	Inference
Application **(Evaluate)**	Understand chemistry concepts in the context of ethno-SSI herbs, solve problems, and find solutions by drawing conclusions based on moral reasoning, data interpretation, and scientific evidence so that chemistry learning becomes more contextualized.	- Apply the Ethno-SSI context of burning snail satay in everyday life on exercise/evaluation questions. - Work on questions in the application stage using the correct method. - Relate the questions to health, culture, environment, religion, social, and chemical processes in the Ethno-SSI context of burning snail satay. - Communicate the results of working on thermochemical Ethno-SSI application questions. - Listen to the lecturer clarify the correct answer. - Reconstruct students' knowledge after the learning process by mentioning what knowledge they have gained, difficulties experienced in the learning process, and alternative solutions to overcome problems. - Make a bibliography and attach evidence of the results of the Ethno-SSI practicum/project activities.	Strategy and tactics

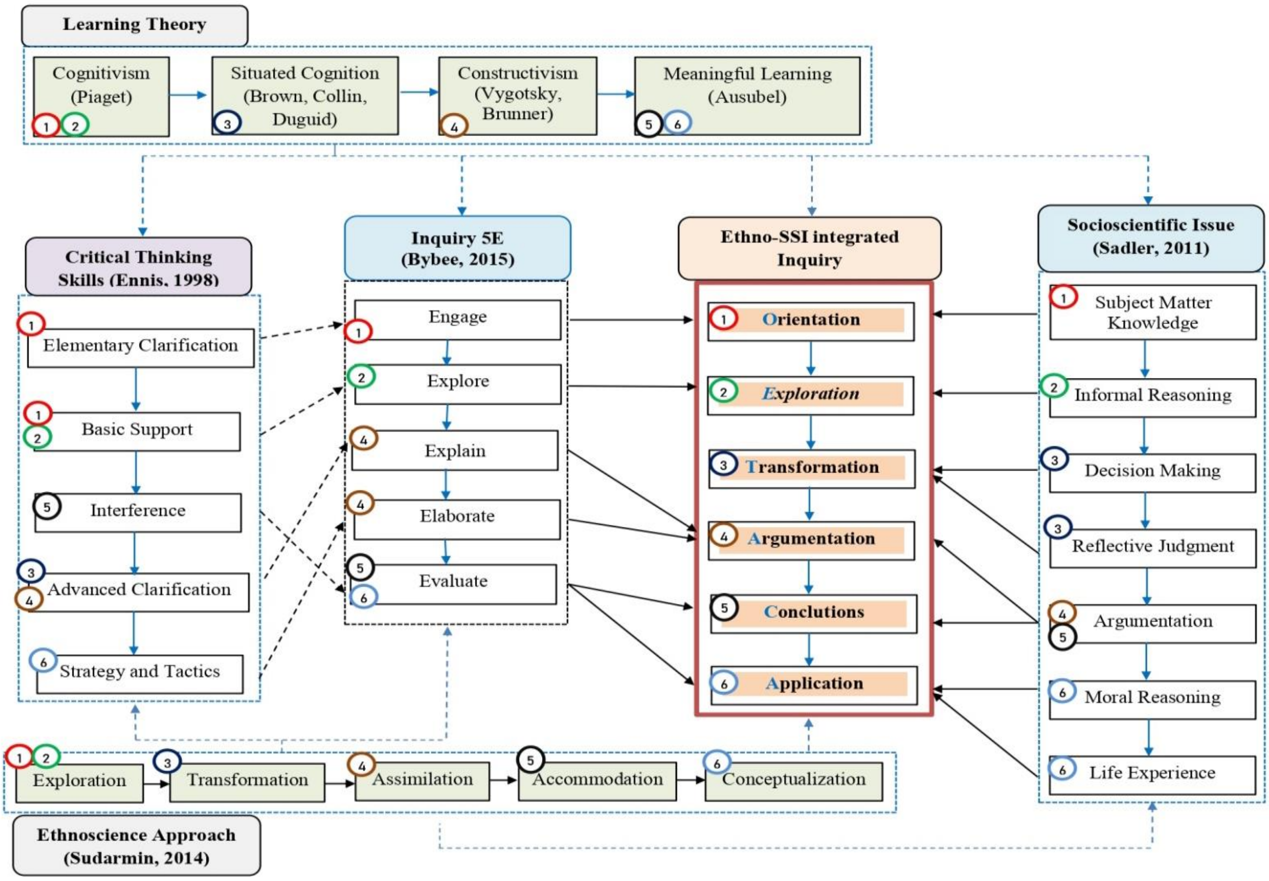


Figure 4. The conceptual framework of inquiry integrated Ethno-SSI syntax OETACA with critical thinking skills.
Source: Elaborated by the author using data from Ennis (1998), Bybee (2015), Sadler (2011) and Sudarmin (2014).

3.1.1. Orientation

The first phase is Orientation, which is a modification of Engage in Bybee (2015) inquiry. It aims to increase the elementary clarification indicator in critical thinking skills. Orientation is a step to foster a responsive atmosphere or climate at the beginning of learning (Cavagnetto, 2010; Chang and Park, 2020; Duschl and Bybee, 2014). In Phase 1, "Orientation", students in groups read discourse, watch videos, analyze existing problems related to thermochemical material in the context of burning snail satay, and then formulate the problem. On the student worksheet, video links, article links, and material links that students can access have been provided so that group activities carried out by students are watching videos, reading articles, and then recording interesting findings and problems from videos and articles that have been accessed. Students are asked to identify the concept of Ethno-SSI problems of burning snail satay in terms of scientific, environmental, health, religious, cultural, and social aspects and then formulate problems related to the context of Thermochemistry. The following identifies the Ethno-SSI context of burning snail satay, shown in **Table 10**.

Table 10. Orientation phase of the process of burning snail satay context.

Ethno-SSI Aspects	Explanation
Health	- Snail slime is considered to have antibacterial and anticancer properties. - Snail mucus can treat tuberculosis, asthma, and toothache. It is also believed to have cosmetic properties that improve the appearance and smoothness of the skin. - Charcoal-grilled meat can be a carcinogen. - Snails are animals that can host various microorganisms, including pathogens, germs, bacteria, and parasites.
Religion	- There is a debate among scholars and religious experts regarding the halal or haram of eating snails. - Certain foods may be considered haram if they are deemed unclean or impure. However, if they are found to have beneficial properties for human health, they may be considered halal or permissible for consumption.
Culture	Snail satay is a local wisdom regional specialty food maintained today because it is believed to benefit the community.
Environment	- Snail processing waste, such as shells and dung, can be used as fertilizer. - Some people consider snails pests because of their rapidly growing population, which lays eggs and damages crops. - The smoke from burning snail satay contains CO and CO2 gas, can cause shortness of breath/asthma.
Social	The processing of snail satay can be a livelihood for the community and increase income.

3.1.2. Exploration

The second phase is Exploration, which is the same as Bybee (2015) exploration phase, which aims to improve the Basic Support indicators in critical thinking skills. In Phase 2 "Exploration," activities are designed by making observation sheets, interviews, and documentation at the place where the snail satay Ethno-SSI product is produced. Students are asked to explore where the Ethno-SSI context is made, then write down the interview results in a student worksheet and attach evidence of the observations and interviews. This interview and documentation activities are conducted to obtain data on the community's original knowledge regarding manufacturing procedures, the benefits of the products, and controversial issues. In addition to direct observation and interviews with Ethno-SSI producers of snail satay, students are asked to find supporting references from several sources, including books, scientific journal articles, news in the mass media/online, or other sources relevant to thermochemistry. These references will later become references in scientific science transformation activities.

3.1.3. Transformation

The third phase is Transformation, an additional modification of the Bybee (2015) phase that aims to improve the Advanced Clarification indicators in critical thinking skills. In Phase 3 "Transformation", after data collection activities related to the original science knowledge of the community are fulfilled, the next step is to provide a scientific explanation for the findings. Scientific explanation in the ethnoscience approach is included in the transformation stage (Diliarosta *et al.*, 2021). At this stage, scientific explanations of evidence and claims from indigenous knowledge form scientific or ethnoscientific knowledge as a product of the synergy of culture and science (Sumarni *et al.*, 2022; Zidny *et al.*, 2020). Students are asked to provide a checklist and then fill in the table provided to transform indigenous knowledge into scientific knowledge. In the transformation phase, the student worksheet also contains Ethno-SSI practicum activities to prove the Ethno-SSI context scientifically, and students are asked to write independently the practicum procedures to be carried out. Examples of discussions from the Indigenous Knowledge interview results that can be transformed into Scientific Knowledge are shown in **Table 11**.

Table 11. Ethno-SSI transformation of snail satay burning.

No.	Indigenous Knowledge	Scientific Knowledge
1	The fuel for burning snail satay uses wood-type charcoal because wood is relatively cheaper and easier to obtain.	Wood burning requires a specific activation energy to start a chemical reaction. After burning, an exothermic reaction that releases energy occurs, but this process is not instant and occurs gradually. Wood charcoal is good for cooking because it contains high carbon produced from carbonizing wood with a high cellulose content.
2	Cooking oil/kerosene added to charcoal can accelerate the flame in the combustion process.	The heat decomposes the hydrocarbon chain from the cooking oil/kerosene into a gas from its generation, creating a fire to burn charcoal faster. This is because as the hydrocarbon bonds in the combustion reaction release the energy stored in the bonds, a hotter flame will be created.
3	Burning using charcoal takes longer.	For charcoal to burn, oxygen in the air must enter the solid structure, meet up with the surface of the carbon, and undergo a chemical reaction with the carbon to produce heat and, after some seconds, fire. This process is slower because of the restricted access to air and the chemical reactions that must take place within the solid structure of the charcoal.
4	When burning a snail satay, the heat from the burning will be felt around it.	The system and environment are related to the context of burning snail satay and charcoal. When burning snails stay, heat is transferred from the system to the environment, causing people around it to feel warm.
5	Burning snail satay meat is not suitable for health.	If it contains lots of carbon, high consumption of burnt satay can be carcinogenic because it forms carcinogenic compounds like polycyclic aromatic hydrocarbons (PAH) and heterocyclic amines (HCA), which can enhance cancer risk. If the snail satay is too burned, the ingredients are burned, and the nutrients in the satay will also be destroyed.

In addition to scientific transformation, the activities in this phase are also carried out by investigating directly through practicum activities to make charcoal from organic waste. Charcoal is a black residue containing impure carbon substances produced by removing the existing water content and derived from volatile components in animals or plants. Charcoal is generally made by heating or burning other organic or inorganic objects. This black-colored, easily crushed, lightweight, coal-like charcoal has a substance consisting of 85% to 98% carbon, and the rest is ash or other chemicals. Several types of charcoal are distinguished based on the origin of the raw materials, such as wood charcoal, rice husks, coconut husks, coconut shells, corn stalks, litter/leaves, bamboo, and fruit skins such as durian, mahogany, cocoa, and cotton/and skins. Using charcoal to utilize household waste can save fuel and be more environmentally friendly. **Table 12** below briefly investigates charcoal's calorific value and moisture content.

Table 12. Determination of calorific value and moisture content of charcoal.

No.	Charcoal Type	Temperature after charcoal (0C)	Mass before heating (gr)	Mass after heating	Moisture content (%)
1	Wood charcoal	56.8	81.206	80.505	4.1
2	Wood dust charcoal	62.8	69.240	64.629	48.8
3	Rice husk charcoal	43	95.200	95.15	54
4	Coconut fiber charcoal	80.5	9.425	6.809	27.75
5	Coconut shell charcoal	89.3	95.492	94.800	10.28
6	Corncob charcoal	39.5	19.837	10.240	48.4

The results of making charcoal from organic waste by a prospective chemistry teacher are shown in **Fig. 5**.

Figure 5. Practicum for making charcoal from organic waste in thermochemical concept.

Based on investigations conducted by prospective chemistry teachers and data from practicum results, the better organic waste used as charcoal is the type of coconut shell. This is because coconut shell charcoal has a higher density than charcoal from other materials, so it is more durable and provides more efficient combustion results because the water content is less.

3.1.4. Argumentation

The fourth phase is argumentation, which modifies the explanation and elaboration in Bybee (2015) inquiry and aims to increase the advanced clarification indicator in critical thinking skills. In Phase 4 "Argumentation", students focus on sharing content/material in the interaction between lecturers and students. In this process, students can discuss responding to the Ethno-SSI case of burning snail satay in groups through dialogue, discussion, and debate activities. Students conduct group discussions to analyze the data collected to be able to answer questions at the argumentation stage. Lecturers guide students in conveying the results of activities that have been carried out using their ideas or words so the process of constructing knowledge will be well developed. This argumentation activity aims for students to argue to solve Ethno-SSI problems and to determine the right decision.

This argumentation stage is expected to help students clarify their conceptual understanding and communicate their knowledge in various aspects such as health, religion, environment, culture, and society. In this activity, students record their discussion activities to see the achievement of their ability to argue and decide on problem-solving. Debating activities are used in class discussions to train students' critical thinking about the relationship between science, technology, and society, and to make decisions based on the questions asked (Albe, 2008).

Students develop quality scientific arguments from their investigations using the components of claims, evidence, and explanations (Berland and McNeill, 2010).

- Claim: the answer or conclusion when encountering a problem/question.
- Evidence: support for claims in the form of data obtained during experiments/practicum or from scientific transformation results.
- Explanation: a statement to support the evidence, which is why (rationale) of the evidence you use to support the claim is based on the theory, law, and theories.

3.1.5. Conclusion

The fifth phase is the Conclusion, which modifies the evaluation in Bybee (2015) inquiry to improve the Inference indicator in critical thinking skills. The conclusions are formulated by describing the results of findings obtained based on discussions and scientific transformation in the context of Ethno-SSI of burning snail satay. To arrive at the correct conclusion, the lecturers must show students what information they need to describe in the right way to get important information from the Ethno-SSI problem of burning snail satay. At this stage, the lecturer guides students in formulating conclusions based on the data collected from the results of experiments/practicums and exploratory studies. Based on the practicum results, it can be concluded that the higher the water content in charcoal, the smaller the calorific value; on the contrary, if the water content is low, the calorific value is more significant.

3.1.6. Application

The sixth phase is the Conclusion, a modification of the evaluation in Bybee (2015) inquiry, which aims to improve the strategy and tactics indicator in critical thinking skills. Application is the final stage of this phase. The aim is to evaluate students' critical thinking skills by applying thermochemical problems. After that, students can communicate the results of group discussions in front of the class. This application provides meaningful and contextualized learning for students. Lecturers can reflect on all the activities that have been carried out to see the success of each phase. Giving Ethno-SSI-based practice questions to students positively impacts students in finding more information about the subject matter so that it can improve critical thinking skills. In addition, practice questions allow students to deepen their understanding of learning concepts by applying theory in the context of basic chemistry questions.

3.2. Critical thinkings results using Ethno-SSI integrated inquiry strategy

The results of critical thinking skills obtained through the application of the Ethno-SSI integrated inquiry strategy reflect the ability of prospective chemistry teachers to analyze, evaluate, and apply local wisdom-based chemical knowledge. Prospective chemistry teachers show a deep understanding of thermochemical concepts, such as enthalpy, phase change, and the laws of thermodynamics. They can relate theory to daily practice, especially in local culture, such as how the burning process in snail satay affects energy and temperature changes and tell it to the principles of thermochemistry. Significant improvement in students' critical thinking skills can be seen using the Normalized Gain (N-gain) test shown in **Table 13**.

Table 13. Improvement of students' critical thinking skills.

Class	Pretest Average	Posttest Average	N-Gain <g>	Category
Offering A and B	43.6538	83.7179	0.70132	High

The increase in critical thinking skills is expressed by the normalized gain test based on the pretest and posttest scores on offering A and B to as many as 52 students. The normalized gain test results show that improving critical thinking skills in offering A and B is included in the high category (N-Gain = 0.7). The results of the statistical calculations are shown in **Table 14**.

Table 14. Statistical calculation results analysis.

Category	Pretest	Posttest
$\sum X$	2270	4353.333
χ	43.6538	83.7179
Max	80	96.6667
Min	20	66.6667
s^2	97375,7	357492
s	312.05	597.905
Range	60	30

The data in **Table 14** show that the average posttest (83.71) increased from the pretest (43.65). These results indicate that the ethno-SSI integrated inquiry strategy teaches prospective chemistry teachers to produce scientific knowledge and skills to address ethno-SSI issues related to chemistry learning. This strategy also helps prospective chemistry teachers build relationships and correlations between culture, science, and the environment and encourages critical and systematic thinking in addressing various problems. The critical thinking skills test score data was also analyzed per indicator to obtain an overview of each indicator of critical thinking skills, according to Ennis, as shown in **Table 15**.

Table 15. Student critical thinking skills test results per indicator.

No.	Critical Thinking Skills Indicator	Average score per indicator	Category
1	Elementary Clarification	85	Very High
2	Basic Support	75	Medium
3	Interference	80	High
4	Advanced Clarification	78	Medium
5	Strategy and Tactics	75	Medium

3.2.1. Elementary clarification

Critical thinking skills on the indicator of providing simple explanations in this study, including obtaining the highest skill level among other indicators with an average score of 85. This finding shows prospective chemistry teachers can formulate and answer questions by reading and understanding the content. Prospective chemistry teachers can also correctly write chemical symbols or formulas in question questions and their equations. This is because, during the learning process, prospective chemistry teachers are continuously trained to work on chemistry questions on Thermochemistry that are integrated with the Ethno-SSI context. In this indicator, prospective chemistry teachers are expected to be able to identify images, diagrams, and symbols based on the information contained in the problem. According to Ennis, (1990), students can think critically by making habits that are continuously carried out, such as formulating questions and answering questions that require explanation.

Indicators of critical thinking skills in the Elementary Clarification aspect include questions that focus on research activities, assessing a statement, and answering questions relevant to the explanation according to the Ethno-SSI context. This indicator can evaluate the possibility of prospective chemistry teachers in formulating appropriate problem specifications by recognizing important components and using images, diagrams, and symbols to describe scenarios based on data and facts (Masni *et al.*, 2020). The findings in the study showed that prospective chemistry teachers made few mistakes when solving problems, such as a lack of reading and understanding of Ethno-SSI content. Students who answered incorrectly on this indicator indicated that they could not understand the significance of the Ethno-SSI problem due to failure to remember or understand the content of the material discussed. Students can also not transcribe known facts from the problem in pictures, tables, or diagrams, so prospective chemistry teachers need to be trained in formulating problems and answering based on data and their knowledge related to material content (Fijar *et al.*, 2019).

3.2.2. Basic support

Students' critical thinking skills on the Basic Support indicator obtained an average score of 75 in the medium category. The results of this indicator show that prospective chemistry teachers can determine the proper steps to analyze problems based on concepts and phenomena that exist in Ethno-SSI questions, even though the results are not optimal, and not all answers are correct. This shows that many prospective chemistry teachers still have not been able to analyze the phenomena and symptoms that arise from the statements in the problem, which are essential information related to the Ethno-SSI context, so it is not easy to analyze. In Ethno-SSI questions, some prospective chemistry teachers experience errors when identifying the relationship between concepts and statements or phenomena. This can happen because so far, prospective chemistry teachers tend to memorize material and less at the time of application with the local context or SSI, so even though students know the concept but do not know how to apply it in everyday life (Kasi and Widodo, 2022).

In this indicator, students are asked to establish the credibility of a source and research and assess the results of research on the topic of explaining enthalpy changes and types of enthalpy and explaining energy and energy changes in chemical reactions. This study's basic support indicator measures prospective chemistry teachers' skills in analyzing assumptions, using procedures, and existing investigations to solve problems (Maknun, 2020). This indicator considers whether the source of information presented in the issue is reliable or not (Nurdin *et al.*, 2018).

3.2.3. Interference

Students' critical thinking skills on the Interference indicator obtained an average score of 80 in the high category. This indicator was identified by the element needed to conclude report data, principles, judgments, beliefs or opinions, concepts, and descriptions with the Ethno-SSI context. The question on this indicator discusses drawing findings related to thermochemistry in burning snail satay. Shows the attitude and ability to understand and analyze Ethno-SSI problems from various factors so prospective chemistry teachers can draw the correct conclusions. By developing skills in this indicator, prospective chemistry teachers will become more competent in understanding scientific concepts and more sensitive to the social and environmental context in which they are located. This indicator can also prepare prospective chemistry teachers to become individuals who think critically and responsibly when facing the challenges of a complex society.

3.2.4. Advanced clarification

Critical thinking ability on the indicator of providing a further explanation has the lowest value compared to other indicators. Based on the analysis of student answers, a score of 78 was obtained in the moderate category; this was due to the low initial knowledge of prospective chemistry teachers about the concept of thermochemistry, making it difficult to relate to the Ethno-SSI context. The indicator of providing a further explanation in this study was carried out by constructing arguments by analyzing and providing explanations in the form of defining terms, considering definitions using appropriate criteria, and identifying assumptions in the Ethno-SSI context. In this indicator, many prospective chemistry teachers still have not been able to identify assumptions. Answering these questions requires a sufficient understanding of the material; if students do not master the material, it will affect them in identifying assumptions and solving problems, especially in describing equations from several related equations or finding relationships from several thermochemical equations.

3.2.5. Strategy and tactics

Critical thinking skills on indicators of organizing strategies and tactics score 75 with a low category. Based on the analysis results, most prospective chemistry teachers have not been able to decide the proper action to solve problems in the problem, especially when using thermochemical formulas or equations. Indicators Organising strategies and tactics is done by considering possible solutions to solve Ethno-SSI context problems. Prospective chemistry teachers can think with their knowledge to formulate an alternative solution by solving problems that occur, especially using formulas by the thermochemistry concept. If prospective chemistry teachers are not trained to think critically and analytically, they will have difficulty designing effective strategies and tactics to address real-world Ethno-SSI problems.

3.3. Perception of prospective chemistry teachers using the Ethno-SSI integrated inquiry strategy

Implementation of the inquiry-integrated Ethno-SSI syntax OETACA has positively responded to almost all components. This indicates that the implementation of the inquiry-integrated Ethno-SSI syntax OETACA prototype is very good, where students are very interested when being given a case/problem so that they are motivated to analyze Ethno-SSI problems and can explore independently and in groups. Furthermore, students are motivated to determine the steps of problem-solving and design Ethno-SSI experimental procedures. Experimental procedures designed by students can make it easier to identify chemical concepts and principles so that students can solve Ethno-SSI cases given by lecturers. Learning activities through the Ethno-SSI integrated inquiry strategy directly impact students, especially in getting a pleasant learning experience, having the courage to argue, being helped in formulating problems, more easily understanding and comprehending the material studied, and having a high willingness to attend lectures. Furthermore, the graph of student responses to the Ethno-SSI integrated inquiry strategy is shown in **Fig. 6**.

Based on the responses to the Ethno-SSI integrated inquiry strategy, as shown in **Fig. 2**, most (92%) agreed and strongly agreed to implement this strategy in chemistry learning in the classroom. This strategy proved to be practical and effective in facilitating understanding of chemical concepts, primarily related to Ethno-SSI problems encountered, such as in the context of Thermochemistry, namely burning snail satay. Chemistry teacher candidates (78%) agreed and strongly agreed that the Ethno-SSI inquiry steps (orientation, exploration, transformation, argumentation, conclusion, and application) improve critical thinking skills. These results align with research by Zidny and Eilks (2022) that ethnoscience and SSI will be actively involved through scientific inquiry activities such as exploration, practical activities in the laboratory, data analysis, and scientific argumentation that require logical reasoning.

Another finding is that the % of chemistry teacher candidates 75% agreed that this strategy teaches how to reconstruct indigenous knowledge into scientific knowledge in the context of Ethno-SSI. Ethnoscience is a learning approach that contains activities to reconstruct indigenous knowledge into scientific knowledge that can be accounted for related to local wisdom (Dewi *et al.*, 2022; Diliarosta *et al.*, 2021; Sudarmin *et al.*, 2020). This strategy can improve critical thinking skills in solving the Ethno-SSI context 84% of prospective chemistry teachers agreed. The results of many previous studies mention that ethnoscience-based learning approaches (Prayogi *et al.*, 2023; Sudarmin *et al.*, 2019; Zidny *et al.*, 2020) and SSI (Barrue and Albe, 2013; Borgerding and Dagistan, 2018; Yacoubian and Khishfe, 2018) can improve critical thinking skills.

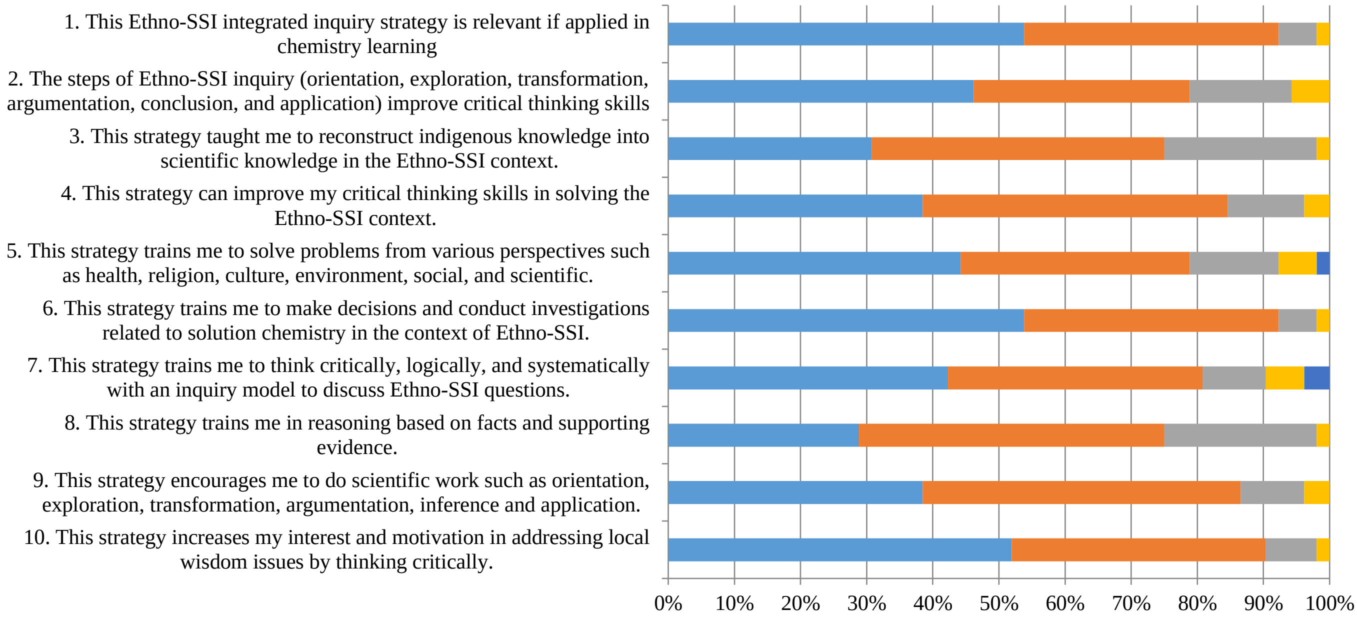


Figure 6. Responses of prospective chemistry teachers (N=52) to the Ethno-SSI integrated inquiry strategy.

This strategy trains in solving problems from various perspectives such as health, religion, culture, environment, social, and scientific 78% of prospective chemistry teachers answered in the affirmative. Learning with the SSI strategy trains problem-solving from various perspectives, including social, environmental, economic, and political, based on applicable morals and ethics (Herman *et al.*, 2021; 2019; Holbrook *et al.*, 2020; Raveendran, 2021; Songer and Ibarrola Recalde, 2021). This strategy trains in making decisions and conducting investigations related to solution chemistry materials in the Ethno-SSI context, and 92% agree. This is by the results of research by Gupta *et al.* (2015) which states that learning chemistry with guided inquiry instruction can improve critical thinking skills through investigation and decision-making activities. Another study mentioned that the inquiry learning model with the 5E cycle (engagement, exploration, explanation, elaboration, evaluation) using the SSI context effectively improves critical thinking skills (Cahyarini *et al.*, 2016).

The statement that this strategy trains me to think critically, logically, and systematically with the inquiry model to discuss Ethno-SSI questions received a response of 82% agree. The inquiry learning model can help prospective chemistry teachers think critically, logically, and systematically by searching, finding, and analyzing information independently to make learning more active (Capps and Crawford, 2013; Wenning, 2011). This inquiry-learning model can improve critical thinking skills by creating an engaging and interactive learning environment through experimentation and proof based on relevant evidence (Adnan *et al.*, 2021; Cheung *et al.*, 2020). This strategy trains in expressing reasons based on facts and supporting evidence 75% of prospective chemistry teachers agreed. This finding shows prospective chemistry teachers need alternative learning strategies to help them understand, analyze data, and make decisions based on facts and evidence. In Thermochemistry, prospective chemistry teachers are involved in experimental activities such as thermochemical practicum, energy calculation, and basic theory of thermochemical concepts. Activities linking scientific facts with socioscientific issues can improve students' critical thinking skills.

This strategy encourages prospective chemistry teachers to do scientific work such as orientation, exploration, transformation, and argumentation, and 85% agree. Ethno-SSI integrated inquiry learning strategy is an innovative learning strategy constructed to train the critical thinking skills of prospective chemistry teachers. This strategy combines inquiry learning models with ethnoscience approaches and socioscientific issues related to local wisdom. Thus, prospective chemistry teachers not only learn about chemistry concepts but also understand how these concepts can relate to everyday life and the challenges faced by controversial, dilemmatic, and complex issues (Rahayu, 2019; Saija *et al.*, 2022). This strategy increases the interest and motivation of prospective chemistry teachers in addressing local wisdom issues with critical thinking 91% agree. Chemistry learning associated with the context of ethnoscience and socioscientific issues can increase awareness of the importance of social and environmental impacts so that the interest of prospective chemistry teachers can increase to contribute to addressing these issues (Zidny and Eilks, 2022).

4. Conclusions

The successfully developed Ethno-SSI integrated inquiry strategy is a learning strategy that incorporates local wisdom to improve the critical thinking skills of prospective chemistry teachers. The syntax of this learning strategy includes six phases, namely: (1) orientation, (2) exploration, (3) transformation, (4) argumentation, (5) conclusion, and (6) application. The Ethno-SSI integrated inquiry learning strategy has fulfilled the valid and practical requirements. The validation results with CVI of the Ethno-SSI integrated inquiry strategy in the content aspect received a score of 0.83 and a construct aspect of 0.93 in the high category. The results of the critical thinking skills test instrument validation received a CVI score of 0.90, while the questionnaire received a score of 0.89, both of which were in the high category. The practicality of the Ethno-SSI integrated inquiry strategy is based on the assessment of learning implementation, which obtained an average learning implementation of 86.25% with a convenient category. The results of the critical thinking skills test on a small scale show an N-gain of 0.7 in the high category, but the criteria for each indicator are in the moderate category. The results of prospective chemistry teachers' responses to the Ethno-

SSI integrated inquiry strategy, on average, gave a positive response to each component with the categories strongly agree (43%), agree (41%), undecided (12%), disagree (3%), strongly disagree (1%).

5. Recommendation

Further research is recommended to implement the inquiry-Ethno-SSI strategy with OETAKA syntax on a large scale by conducting an effectiveness test on the strategy developed. The context of local wisdom studied is more relevant to chemistry learning. This research can also be conducted at several universities to obtain many data sources. The instruments and teaching materials developed can be adjusted to the Ethno-SSI context to make chemistry learning more exciting and relevant.

6. Limitation

This research only focuses on the topic of Thermochemistry. The local wisdom raised is only related to the burning snail staying in an area prospective chemistry teachers may not know. The data collected in this study is only limited to small-scale trials, so it is less specific and quantitatively in-depth. This research requires a long time in field exploration activities because students must still be trained in observation and interview activities.

Authors' contribution

Conceptualization: Ratna Kumala Dewi; Sri Rahayu; **Data curation**: Muntholib Muntholib; Ratna Kumala Dewi; **Formal Analysis**: Woro Sumarni; **Funding acquisition**: Not applicable; **Investigation**: Ratna Kumala Dewi; **Methodology**: Ratna Kumala Dewi; Sri Rahayu; **Project administration**: Ratna Kumala Dewi; **Resources**: Muntholib Muntholib; **Software**: Not applicable; **Supervision**: Sri Rahayu; **Validation**: Woro Sumarni; **Visualization**: Ratna Kumala Dewi; **Writing – original draft**: Ratna Kumala Dewi; Sri Rahayu; Muntholib Muntholib; Woro Sumarni; **Writing – review & editing**: Ratna Kumala Dewi; Sri Rahayu; Muntholib Muntholib; Woro Sumarni.

Data availability statement

The data will be available upon request.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

Abdurrahman, H.; Wildan, W.; Loka, I. N. The Effect of Guided Inquiry Learning Model on Chemistry Learning Towards Critical Thinking Skills Students at Class XI MIA SMAN 7 Mataram 2019. *Chemistry Education Practice*. **2020**, *3* (2), 99–103. https://doi.org/10.29303/cep.v3i2.1817

Adal, E. E.; Cakiroglu, J. Investigation of Preservice Science Teachers' Nature of Science Understanding and Decision Making on Socioscientific Issue through the Fractal Model. *Science and Education*. **2022**, *32*, 529–565. https://doi.org/10.1007/s11191-022-00319-1

Adnan, G.; Zulfikar, T.; Armia, M. S.; Gade, S.; Walidin, W. Impacts of Inquiry Learning Model on Students' Cognitive and Critical Thinking Ability. *Cypriot Journal of Educational Sciences*. **2021**, *16* (3), 1290–1299. https://doi.org/10.18844/CJES.V16I3.5851

Aiman, U.; Hasyda, S.; Uslan the Influence of Process Oriented Guided Inquiry Learning (POGIL) Model Assisted by Realia Media to Improve Scientific Literacy and Critical Thinking Skill of Primary School Students. *European Journal of Educational Research*. **2020**, *9* (4), 1635–1647. https://doi.org/10.12973/EU-JER.9.4.1635

Albe, V. Students' Positions and Considerations of Scientific Evidence about a Controversial Socioscientific Issue. *Science and Education*. **2008**, *17* (8–9), 805–827. https://doi.org/10.1007/s11191-007-9086-6

Alim; Sarwi; Subali, B. Implementation of Ethnoscience-Based Guided Inquiry Learning on The Scientific Literacy and The Character of Elementary School Students. *Journal of Primary Education*. **2020**, *9* (2), 139–147. https://doi.org/10.15294 /jpe.v9i2.29189

Arsal, Z. The Impact of Inquiry-Based Learning on the Critical Thinking Dispositions of Pre-Service Science Teachers. *International Journal of Science Education*. **2017**, *39* (10), 1326–1338. https://doi.org/10.1080/09500693.2017.1329564

Barak, M.; Dori, Y. J. Enhancing Higher Order Thinking Skills among Inservice Science Teachers via Embedded Assessment. *Journal of Science Teacher Education*. **2009**, *20* (5), 459–474. https://doi.org/10.1007/s10972-009-9141-z

Barrue, C.; Albe, V. Citizenship Education and Socioscientific Issues: Implicit Concept of Citizenship in the Curriculum, Views of French Middle School Teachers. *Science and Education*. **2013**, *22* (5), 1089–1114. https://doi.org/10.1007/s11191-012-9571-4

Bechtel, R. Oral Narratives: Reconceptualising the Turbulence between Indigenous Perspectives and Eurocentric Scientific Views. *Cultural Studies of Science Education*. **2016**, *11* (2), 447–469. https://doi.org/10.1007/s11422-014-9659-z

Bencze, L.; Pouliot, C.; Pedretti, E.; Simonneaux, L.; Simonneaux, J.; Zeidler, D. SAQ, SSI and STSE Education: Defending and Extending "Science-in-Context." *Cultural Studies of Science Education*. **2020**, *15* (3), 825–851. https://doi.org/10.1007/s11422-019-09962-7

Berland, L. K.; McNeill, K. L. A Learning Progression for Scientific Argumentation: Understanding Student Work and Designing Supportive Instructional Contexts. *Science Education*. **2010**, *94* (5), 765–793. https://doi.org/10.1002/sce.20402

Boholano, H. Smart Social Networking: 21st Century Teaching and Learning Skills. *Research in Pedagogy*. **2017**, *7* (1), 21–29. https://doi.org/10.17810/2015.45

Borgerding, L. A.; Dagistan, M. Preservice Science Teachers' Concerns and Approaches for Teaching Socioscientific and Controversial Issues. *Journal of Science Teacher Education*. **2018**, *29* (4), 283–306. https://doi.org/10.1080/1046560X.2018.1440860

Bybee, R. W. *The BSCS 5E Instructional Model: Creating Teachable Moments*; National Science Teachers Association: United States of America, 2015.

Cahyarini, A.; Rahayu, S.; Yahmin, Y. The Effect of 5E Learning Cycle Instructional Model Ssing Socioscientific Issues (SSI) Learning Context on

Students' Critical Thinking. *Jurnal Pendidikan IPA Indonesia*. **2016**, *5* (2), 222–229. https://doi.org/10.15294/jpii.v5i2.7683

Canel-Çınarbaş, D.; Yohani, S. Indigenous Canadian University Students' Experiences of Microaggressions. *International Journal for the Advancement of Counselling*. **2019**, *41* (1), 41–60. https://doi.org/10.1007/s10447-018-9345-z

Capps, D. K.; Crawford, B. A. Inquiry-Based Instruction and Teaching About Nature of Science: Are They Happening? *Journal of Science Teacher Education*. **2013**, *24* (3), 497–526. https://doi.org/10.1007/s10972-012-9314-z

Cavagnetto, A. R. Argument to Foster Scientific Literacy: A Review of Argument Interventions in K-12 Science Contexts. *Review of Educational Research.* **2010**, *80* (3), 336–371. https://doi.org/10.3102/0034654310376953

Chadwick, R.; McLoughlin, E.; Finlayson, O. E. Teachers' Experience of Inquiry into Socioscientific Issues in the Irish Lower Secondary Science Curriculum. *Irish Educational Studies*. **2023**, *42* (3), 315-337. https://doi.org/10.1080/03323315.2021.1964565

Chang, J.; Park, J. Developing Teacher Professionalism for Teaching Socio-Scientific Issues: What and How Should Teachers Learn? *Cultural Studies of Science Education*. **2020**, *15* (2), 423–431. https://doi.org/10.1007/s11422-019-09955-6

Chen, L.; Xiao, S. Perceptions, Challenges and Coping Strategies of Science Teachers in Teaching Socioscientific Issues: A Systematic Review. *Educational Research Review*. **2021**, *32*, 100377. https://doi.org/10.1016/j.edurev.2020.100377

Cheung, D. H. C.; Ng, A. K. L.; Kiang, K. M.; Chan, H. H. Y. Creating a Community of Inquiry in the Science Classroom: An Effective Pedagogy for Teaching Diverse Students? *Journal of Further and Higher Education*. **2020**, *44* (1), 1–13. https://doi.org/10.1080/0309877X.2018.1491959

Choi, K.; Lee, H.; Shin, N.; Kim, S. W.; Krajcik, J. Re-Conceptualization of Scientific Literacy in South Korea for the 21st Century. *Journal of Research in Science Teaching*. **2011**, *48* (6), 670–697. https://doi.org/10.1002/tea.20424

Council, N. R. *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century (2012)*; The National Academies Press: Washington, DC, 2012. https://doi.org/10.17226/13398

Council, N. R. *National Science Education Standards*; National Academy Press: Washington DC, 2018.

Dauer, J. M.; Sorensen, A. E.; Wilson, J. Students' Civic Engagement Self-Efficacy Varies Across Socioscientific Issues Contexts. *Frontiers in Education*. **2021**, *6,* 628784. https://doi.org/10.3389/feduc.2021.628784

Dawson, V.; Carson, K. Introducing Argumentation About Climate Change Socioscientific Issues in a Disadvantaged School. *Research in Science Education*. **2020**, *50* (3), 863–883. https://doi.org/10.1007/s11165-018-9715-x

Dewi, R. K.; Wardani, S.; Wijayati, N.; Sumarni, W. Demand of ICT-Based Chemistry Learning Media in the Disruptive Era. *International Journal of Evaluation and Research in Education (IJERE)*. **2019**, *8* (2), 265–270. https://doi.org/10.11591/ijere.v8i2.17107

Dewi, R. K.; 'Izzah, A. S. Z.; Anissa, D. D. Implementation of Tulungagung Local Wisdom and Correlation of Islamic Values as a Source of Etnoscience Learning (Phenomenological Studies on Implementation of Tulungagung Local Wisdom). *Annual International Conference on Islamic Education for Students*. **2022**, *1* (1), 1–12. https://doi.org/10.18326/aicoies.v1i1.223

Diliarosta, S.; Sudarmin; Efendi, A.; Dillasamola, D.; Oktomalioputri, B.; Ramadhani, R. Reconstruction and Scientific Explanation of Akar Kuning (Arcangelisia Flava Merr.) from West Sumatra as Ethnomedicine and Source of Science Learning. *Pharmacognosy Journal*. **2021**, *13* (1), 206–211. https://doi.org/10.5530/pj.2021.13.29

Diwu, C. T.; Ogunniyi, M. B. Dialogical Argumentation Instruction as a Catalytic Agent for the Integration of School Science with Indigenous Knowledge Systems. *African Journal of Research in Mathematics, Science and Technology Education*. **2013**, *16* (3), 333–347. https://doi.org/10.1080/10288457.2012.10740749

Duschl, R. A.; Bybee, R. W. Planning and Carrying out Investigations: An Entry to Learning and to Teacher Professional Development around NGSS Science and Engineering Practices. *International Journal of STEM Education*. **2014**, *1* (1), 1–9. https://doi.org/10.1186/s40594-014-0012-6

Dwianto, A.; Wilujeng, I.; Prasetyo, Z. K.; Suryadarma, I. G. P. The Development of Science Domain Based Learning Tool Which Is Integrated with Local Wisdom to Improve Science Process Skill and Scientific Attitude. *Jurnal Pendidikan IPA Indonesia*. **2017**, *6* (1), 23–31. https://doi.org/10.15294/jpii.v6i1.7205

Eastwood, J. L.; Sadler, T. D.; Zeidler, D. L.; Lewis, A.; Amiri, L.; Applebaum, S. Contextualizing Nature of Science Instruction in Socioscientific Issues. *International Journal of Science Education*. **2012**, *34* (15), 2289–2315. https://doi.org/10.1080/09500693.2012.667582

Ennis, R. H. The Extent to Which Critical Thinking Is Subject-Specific: Further Clarification. *Educational Researcher*. **1990**, *19* (4), 13–16. https://doi.org/10.3102/0013189X019004013

Ennis, R. H. Critical Thinking Assessment. *Theory Into Practice*. **1993**, *32* (3), 179–186. https://doi.org/10.1080/00405849309543594

Ennis, R. H. Is Critical Thinking Culturally Biased? *Teaching Philosophy*. **1998**, *21* (1), 15-33.

Ennis, R. H. Critical Thinking: Reflection and Perspective Part I. *Inquiry: Critical Thinking Across the Disciplines*. **2011a**, *26* (1).

Ennis, R. H. Critical Thinking: Reflection and Perspective Part II. *Inquiry: Critical Thinking across the Disciplines*. **2011b**, *26* (2).

Ennis, R. H. Commentary on: Robert H. Ennis' "Critical Thinking across the Curriculum (CTAC)." *Ontario Society for the Study of Argumentation Biennial Conference*. **2013**.

Facione, P. A. *Critical Thinking*: What It Is and Why It Counts; 2011.

Fadly, D.; Rahayu, S.; Dasna, I. W.; Yahmin, Y. The Effectiveness of a SOIE Strategy Using Socio-Scientific Issues on Students Chemical Literacy. *International Journal of Instruction*. **2022**, *15* (1), 237–258. https://doi.org/10.29333/iji.2022.15114a

Fijar, N. A.; Saptono, S.; Masturi, M. Implementation of Guided Inquiry Learning To Improve The Critical Thinking Skills of Junior High School Students. *Journal of Innovative Science Education*. **2019,** *8* (3), 306–314.

Fuad, N. M.; Zubaidah, S.; Mahanal, S.; Suarsini, E. Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning. *International Journal of Instruction*. **2017**, *10* (1), 101–116. https://doi.org/10.12973/iji.2017.1017a

Genel, A.; Topçu, M. S. Turkish Preservice Science Teachers' Socioscientific Issues-Based Teaching Practices in Middle School Science Classrooms. *Research in Science and Technological Education*. **2016**, *34* (1). https://doi.org/10.1080/02635143.2015.1124847

Goldkuhl, G. Practical Inquiry as Action Research and Beyond. *European Conference on Information Systems*. **2008**.

Grace, M.; Lee, Y. C.; Asshoff, R.; Wallin, A. Student Decision-Making about a Globally Familiar Socioscientific Issue: The Value of Sharing and Comparing Views with International Counterparts. *International Journal of Science Education*. **2015**, *37* (11), 1855–1874. https://doi.org/10.1080/09500693.2015.1054000

Guilford, J. P.; Fruchter, B. *Fundamental Statistics in Psychology and Education*; McGraw-Hill: New York, 1978.

Gupta, T.; Burke, K. A.; Mehta, A.; Greenbowe, T. J. Impact of Guided-Inquiry-Based Instruction with a Writing and Reflection Emphasis on Chemistry Students' Critical Thinking Abilities. *Journal of Chemical Education*. **2015**, *92* (1), 32–38. https://doi.org/10.1021/ed500059r

Herman, B. C.; Newton, M. H.; Zeidler, D. L. Impact of Place-Based Socioscientific Issues Instruction on Students' Contextualization of Socioscientific Orientations. *Science Education*. **2021**, *105* (4). https://doi.org/10.1002/sce.21618

Herman, B. C.; Owens, D. C.; Oertli, R. T.; Zangori, L. A.; Newton, M. H. Exploring the Complexity of Students' Scientific Explanations and Associated Nature of Science Views Within a Place-Based Socioscientific Issue Context. *Science and Education*. **2019**, *28* (3–5), 329–366. https://doi.org/10.1007/s11191-019-00034-4

Hofstein, A.; Eilks, I.; Bybee, R. Societal Issues and Their Importance for Contemporary Science Education-a Pedagogical Justification and the State-of-the-Art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education*. **2011**, *9* (6), 1459–1483. https://doi.org/10.1007/s10763-010-9273-9

Holbrook, J.; Rannikmäe, M.; Chowdhury, T. Socioscientific Issues within Science Education and Their Role in Promoting the Desired Citizenry. *Science Education International*. **2020**, *31* (2), 203–208. https://doi.org/10.33828/sei.v31.i2.10

Hunnicutt, S. S.; Grushow, A.; Whitnell, R. Impact of Guided-Inquiry-Based Instruction with a Writing and Reflection Emphasis on Chemistry Students' Critical Thinking Abilities. *Jurnal Pendidikan IPA Indonesia*. **2015**, *4* (1), 32–38. https://doi.org/10.1021/ed500059r

Hussin A. A. Education 4.0 Made Simple: Ideas For Teaching. *International Journal of Education and Literacy Studies*. **2018**, *6* (3), 92–98.

Irwanto; Rohaeti, E.; Prodjosantoso, A. K. Analyzing the Relationships between Pre-Service Chemistry Teachers' Science Process Skills and Critical Thinking Skills. *Journal of Turkish Science Education*. **2019**, *16* (3), 299–313.

Jho, H.; Yoon, H. G.; Kim, M. The Relationship of Science Knowledge, Attitude and Decision Making on Socio-Scientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea. *Science and Education*. **2014**, *23* (5), 1131–1151. https://doi.org/10.1007/s11191-013-9652-z

Kasi, Y. F.; Widodo, A. Integrating Local Science and School Science : The Benefits for the Preservation of Local Wisdom and Promoting Students' Learning. **2022**, 1–22.

Ke, L.; Sadler, T. D.; Zangori, L.; Friedrichsen, P. J. Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socio-Scientific Issues. *Science and Education*. **2021**, *30* (3), 589–607. https://doi.org/10.1007/s11191-021-00206-1

Kölbel, J.; Jentges, E. The Six-Sentence Argument: Training Critical Thinking Skills Using Peer Review. *Management Teaching Review*. **2018**, *3* (2), 118–128. https://doi.org/10.1177/2379298117739856

Kwan, W. Y.; Wong, A. F. L. Effects of the Constructivist Learning Environment on Students' Critical Thinking Ability : Cognitive and Motivational Variables as Mediators. *International Journal of Educational Research*. **2015**, *70*, 68–79. https://doi.org/10.1016/j.ijer.2015.02.006

Ladachart, L.; Ladachart, L. Preservice Biology Teachers' Decision-Making and Informal Reasoning about Culture-Based Socioscientific Issues. *International Journal of Science Education*. **2021**, *43* (5), 641-671. https://doi.org/10.1080/09500693.2021.1876958

Lederman, N. G.; Antink, A.; Bartos, S. Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry. *Science and Education*. **2014**, *23* (2), 285–302. https://doi.org/10.1007/s11191-012-9503-3

Lee, H.; Chang, H.; Choi, K.; Kim, S. W.; Zeidler, D. L. Developing Character and Values for Global Citizens: Analysis of Pre-Service Science Teachers' Moral Reasoning on Socioscientific Issues. *International Journal of Science Education*. **2012**, *34* (6), 925–953. https://doi.org/10.1080/09500693.2011.625505

Leung, J. S. C. A Practice-Based Approach to Learning Nature of Science through Socioscientific Issues. *Research in Science Education*. **2022**, *52* (1), 259–285. https://doi.org/10.1007/s11165-020-09942-w

Lynn, M. R. Determination and Quantification of Content Validity. *Nursing Research*. **1986**, *35* (6), 382–386.

Maknun, J. Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students. *International Education Studies*. **2020**, *13* (6), 117. https://doi.org/10.5539/ies.v13n6p117

Masni, S. E.; Firdaus, L.; Wulandari, S. Increasing Critical Thinking Ability of Students Through Guided Inquiry Model in Learning Photosynthetic Materials in SMA PGRI Pekanbaru. *Journal of Educational Sciences*. **2020**, *4* (2), 285–295.

Mavuru, L.; Ramnarain, U. Learners' Socio-Cultural Backgrounds and Science Teaching and Learning: A Case Study of Township Schools in South Africa. *Cultural Studies of Science Education*. **2020**, *15* (4), 1067–1095. https://doi.org/10.1007/s11422-020-09974-8

Mitarlis; Ibnu, S.; Rahayu, S.; Sutrisno The Effectiveness of New Inquiry-Based Learning (NIBL) for Improving Multiple Higher-Order Thinking Skills (M-HOTS) of Prospective Chemistry Teachers. *European Journal of Educational Research*. **2020**, *9* (3), 1309–1325. https://doi.org/10.12973/eu-jer.9.3.1309

Muskita, M.; Subali, B.; Djukri Effects of Worksheets Base the Levels of Inquiry in Improving Critical and Creative Thinking. *International Journal of Instruction*. **2020**, *13* (2), 519–532. https://doi.org/10.29333/iji.2020.13236a

Nida, S.; Marsuki, M. F.; Eilks, I. Palm-Oil-Based Biodiesel in Indonesia: A Case Study on a Socioscientific Issue That Engages Students to Learn Chemistry and Its Impact on Society. *Journal of Chemical Education*. **2021a**, *98* (8), 2536–2548. https://doi.org/10.1021/acs.jchemed.1c00244

Nida, S.; Mustikasari, V. R.; Eilks, I. Indonesian Pre-Service Science Teachers' Views on Socio-Scientific Issues-Based Science Learning. *Eurasia Journal of Mathematics, Science and Technology Education*. **2021b**, *17* (1), 1–11. https://doi.org/10.29333/ejmste/9573

Nurdin, H.; Jalmo, T.; Ertikanto, C. Effectiveness of Guided Inquiry Model Student Worksheet to Improve Critical Thinking Skill on Heat Material. *International Journal of Advanced Engineering, Management and Science*. **2018**, *4* (7), 564–573. https://doi.org/10.22161/ijaems.4.7.10

Okechukwu, S. A.; Lawrence, A.; Njoku, M. I. A. Innovations in Science and Technology Education: A Case for Ethnoscience Based Science Classrooms. *International Journal of Scientific & Engineering Research*. **2014**, *5* (1), 52–56.

Owens, D. C.; Sadler, T. D.; Petitt, D. N.; Forbes, C. T. Exploring Undergraduates' Breadth of Socio-Scientific Reasoning Through Domains of Knowledge. *Research in Science Education*. **2022**, *52*, 1643–1658. https://doi.org/10.1007/s11165-021-10014-w

Plomp, T.; Nieveen, N.; Akker, J. van den; Bannan, B.; Kelly, A. E. Educational Design Research. *Netherlands Institute for Curriculum Development: SLO*. **2013**, 1–206.

Prayogi, S.; Nyoman, N.; Putu, S. Dynamic Blend of Ethnoscience and Inquiry in a Digital Learning Platform (e- Learning) for Empowering Future Science Educators' Critical Thinking. *Journal of Education and e-*

Learning Research. **2023**, *10* (4), 819–828. https://doi.org/10.20448/jeelr.v10i4.5233

Presley, M. L.; Sickel, A. J.; Muslu, N.; Merle-Johnson, D.; Witzig, S. B.; Izci, K.; Sadler, T. D. A Framework for Socio-Scientific Issues Based Education. *Science Educator*. **2013**, *22* (1), 26–32.

Puig, B.; Evagorou, M. Design of a Socioscientific Issue Unit with the Use of Modeling: The Case of Bees. *International Journal of Designs for Learning*. **2020**, *11* (1), 98–107. https://doi.org/10.14434/ijdl.v11i1.24142

Putri, P. A. W.; Rahayu, S.; Widarti, H. R.; Yahmin, Y. Chemistry Students' Digital Literacy Skills on Thermochemistry Context "Hydrogen Fuel Issue." *Eurasia Journal of Mathematics, Science and Technology Education*. **2022**, *18* (12), em2198. https://doi.org/10.29333/ejmste/12699

Qing, Z.; Jing, G.; Yan, W. Promoting Preservice Teachers' Critical Thinking Skills by Inquiry-Based Chemical Experiment. *Procedia Social and Behavioral Sciences*. **2010**, *2*, 4597–4603. https://doi.org/10.1016/j.sbspro.2010.03.737

Rahayu, S. Promoting the 21st Century Scientific Literacy Skills through Innovative Chemistry Instruction. *AIP Conference Proceedings*. **2017**, *1911*, 020025. https://doi.org/10.1063/1.5016018

Rahayu, S. Socio-Scientific Issues (SSI) in Chemistry Education: Enhancing Both Students' Chemical Literacy & Transferable Skills. *Journal of Physics: Conference Series*. **2019**, *1227* (1), 012008. https://doi.org/10.1088/1742-6596/1227/1/012008

Rahayu, S.; Bambut, K. E. N.; Fajaroh, F. Do Different Discussion Activities in Developing Scientific Argumentation Affect Students' Motivation in Chemistry? *Cakrawala Pendidikan*. **2020**, *39* (3), 679–693. https://doi.org/10.21831/cp.v39i3.32228

Rahayu, S. Chemistry for Life: How to Analyze and Construct Socioscientific Cases for Chemistry Instruction. *AIP Conference Proceedings*. **2021**, *2330*, 020012. https://doi.org/10.1063/5.0043177

Raveendran, A. Invoking the Political in Socioscientific Issues: A Study of Indian Students' Discussions on Commercial Surrogacy. *Science Education*. **2021**, *105* (1), 62–98. https://doi.org/10.1002/sce.21601

Sadler, T. D.; Zeidler, D. L. Patterns of Informal Reasoning in the Context of Socioscientific Decision Making. *Journal of Research in Science Teaching*. **2005**, *42* (1), 112–138. https://doi.org/10.1002/tea.20042

Sadler, T. D.; Donnelly, L. A. Socioscientific Argumentation: The Effects of Content Knowledge and Morality. *International Journal of Science Education*. **2006,** *28* (12), 1463-1488. https://doi.org/10.1080/09500690600708717

Sadler, T. D. Situating Socio-scientific Issues in Classrooms as a Means of Achieving Goals of Science Education. In: *Socio-scientific Issues in the Classroom. Contemporary Trends and Issues in Science Education*. Springer, 2011. https://doi.org/10.1007/978-94-007-1159-4_1

Saija, M.; Rahayu, S.; Fajaroh, F.; Sumari Enhancement of High School Students' Scientific Literacy Using Local-Socioscientific Issues in OE3C Instructional Strategies. *Jurnal Pendidikan IPA Indonesia*. **2022**, *11* (1), 11–23. https://doi.org/10.15294/jpii.v11i1.33341

Songer, N. B.; Ibarrola Recalde, G. D. Eco-Solutioning: The Design and Evaluation of a Curricular Unit to Foster Students' Creation of Solutions to Address Local Socio-Scientific Issues. *Frontiers in Education*. **2021**, *6,* 642320. https://doi.org/10.3389/feduc.2021.642320

Sönmez, E.; Memiş, E. K.; Yerlikaya, Z. The Effect of Practices Based on Argumentation- Based Inquiry Approach on Teacher Candidates' Critical Thinking. *Educational Studies*. **2021**, *47* (1) 59-83 . https://doi.org/10.1080/03055698.2019.1654364

Sudarmin. Pendidikan Karakter,Etnosains dan Kearifan Lokal. In *Fakultas Matematika dan Ilmu Pengetahun Alam, UNNES*. **2014**. http://lib.unnes.ac.id/27040/1/cover_PENDIDIKAN_KARAKTER_SUDARMIN.pdf

Sudarmin, S.; Zahro, L.; Pujiastuti, S. E.; Asyhar, R.; Zaenuri, Z.; Rosita, A. The Development of PBL-Based Worksheets Integrated with Green Chemistry and Ethnoscience to Improve Students' Thinking Skills. *Jurnal Pendidikan IPA Indonesia*. **2019**, *8* (4), 492–499. https://doi.org/10.15294/jpii.v8i4.17546

Sudarmin, S.; Tri Prasetya, A.; Diliarosta, S.; Pujiastuti, R. S. E.; Jumini, S. The Design of Ethnoscience-Based Inquiry Learning for Scientific Explanation about Taxus Sumatrana as Cancer Medication. *Journal for the Education of Gifted Young Scientists*. **2020**, *8* (4), 1493–1507. https://doi.org/10.17478/jegys.792830

Sulistina, O.; Rahayu, S.; Dasna, I. W.; Yahmin The Influence of Guided Inquiry-Based Learning Using Socio-Scientific Issues on Environmental Awareness of Pre-Service Chemistry Teachers. *Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)*. **2021**, *528*, 246–252. https://doi.org/10.2991/assehr.k.210305.036

Sumarni, W.; Sudarmin, S.; Sumarti, S. S.; Kadarwati, S. Indigenous Knowledge of Indonesian Traditional Medicines in Science Teaching and Learning Using a Science–Technology–Engineering–Mathematics (STEM) Approach. *Cultural Studies of Science Education*. **2022**; *17*, 467–510. https://doi.org/10.1007/s11422-021-10067-3

Sutiani, A.; Situmorang, M.; Silalahi, A. Implementation of an Inquiry Learning Model with Science Literacy to Improve Student Critical Thinking Skills. *International Journal of Instruction*. **2021**, *14* (2), 117–138. https://doi.org/10.29333/iji.2021.1428a

Suwahyu, F. A.; Rahayu, S. Development and Utilization of Instrument Using PISA Framework to Improve Chemistry Literacy Ability: A Systematic Review. *AIP Conference Proceedings*. **2023**, *2569*, 030016. https://doi.org/10.1063/5.0113478

Syahrial; Asrial; Kurniawan, D. A.; Perdana, R.; Pratama, R. A. Implementing Inquiry Based Ethno-Constructivism Learning Module to Improve Students' Critical Thinking Skills and Attitudes towards Cultural Values. *Eurasian Journal of Educational Research*. **2021**, *95* (95), 118–138. https://doi.org/10.14689/EJER.2021.95.7

Tajudin, N. M.; Chinnappan, M. The Link between Higher Order Thinking Skills, Representation and Concepts in Enhancing TIMSS Tasks. *International Journal of Instruction*. **2016**, *9* (2), 199–214. https://doi.org/10.12973/iji.2016.9214a

Tan, J. P. L.; Choo, S. S.; Kang, T.; Liem, G. A. D. Educating for Twenty-First Century Competencies and Future-Ready Learners: Research Perspectives from Singapore. *Asia Pacific Journal of Education*. **2017**, *37* (4), 425–436. https://doi.org/10.1080/02188791.2017.1405475

Waard, E. F.; Prins, G. T.; Van Joolingen, W. R. Pre-University Students' Perceptions about the Life Cycle of Bioplastics and Fossil-Based Plastics. *Chemistry Education Research and Practice*. **2020**, *21* (3), 908–921. https://doi.org/10.1039/c9rp00293f

Wahono, B.; Narulita, E.; Chang, C. Y.; Darmawan, E.; Irwanto, I. The Role of Students' Worldview on Decision-Making: An Indonesian Case Study by a Socio-Scientific Issue-Based Instruction Through Integrated STEM Education. *Eurasia Journal of Mathematics, Science and Technology Education*. **2021**, *17* (11), 1–15. https://doi.org/10.29333/ejmste/11246

Wang, H. H.; Hong, Z. R.; Liu, S. C.; Lin, H. S. The Impact of Socio-Scientific Issue Discussions on Student Environmentalism. *Eurasia Journal of Mathematics, Science and Technology Education*. **2018**, *14* (12) em1624. https://doi.org/10.29333/ejmste/95134

Wenning, C. J. Level of Inquiry: Using Inquiry Spectrum Learning Sequences on Teach Science. *Journal of Physics Teacher Eucation Online*. **2011**, *6* (2), 11–20.

Winarti, A.; Iriani, R.; Butakor, P. K.; Meiliawati, R.; Syarpin Transcript-Based Lesson Analysis: The Analysis of Classroom Communication in Chemistry Implementing Case-Based and Project-Based Learning. *Indonesian Journal on Learning and Advanced Education*. **2024**, *6* (2020), 1–13. https://doi.org/10.23917/ijolae.v6i1.23160

Wiyarsi, A.; Prodjosantoso, A. K.; Nugraheni, A. R. E. Promoting Students' Scientific Habits of Mind and Chemical Literacy Using the Context of Socio-Scientific Issues on the Inquiry Learning. *Frontiers in Education*. **2021**, *6*, 660495. https://doi.org/10.3389/feduc.2021.660495

Yacoubian, H. A. Is Science a Universal or a Culture-Specific Endeavor? The Benefits of Having Secondary Students Critically Explore This Question. *Cultural Studies of Science Education*. **2020**, *15* (4), 1097–1119. https://doi.org/10.1007/s11422-020-09975-7

Yacoubian, H. A.; Khishfe, R. Argumentation, Critical Thinking, Nature of Science and Socioscientific Issues: A Dialogue between Two Researchers. *International Journal of Science Education*. **2018**, *40* (7), 796–807. https://doi.org/10.1080/09500693.2018.1449986

Yazidi, R. El; Rijal, K. Science Learning in the Context of "Indigenous Knowledge" for Sustainable Development. *International Journal of Ethnoscience and Technology in Education*. **2024**, *1* (1), 28. https://doi.org/10.33394/ijete.v1i1.10880

Yuanita, L.; Ibrahim, M.; Prahani, B. K. Innovative Chemistry Learning Model: Improving the Critical Thinking Skill and Self-Efficacy of Pre-Service Chemistry Teachers. *Journal of Technology and Science Education*. **2019**, *9* (1), 59–76.

Yuenyong, C. Enhancing Scientific Literacy in Thailand. *Global Studies of Childhood*. **2013**, *3* (1), 86–98. https://doi.org/10.2304/gsch.2013.3.1.86

Zeidler, D. L.; Herman, B. C.; Sadler, T. D. New Directions in Socioscientific Issues Research. *Disciplinary and Interdisciplinary Science Education Research*. **2019**, *1*, 11. https://doi.org/10.1186/s43031-019-0008-7

Zeidler, D. L.; Sadler, T. D.; Applebaum, S.; Callahan, B. E. Advancing Reflective Judgment through Socioscientific Issues. *Journal of Research in Science Teaching*. **2009**, *46* (1), 74–101. https://doi.org/10.1002/tea.20281

Zidny, R.; Eilks, I. Learning about Pesticide Use Adapted from Ethnoscience as a Contribution to Green and Sustainable Chemistry Education. *Education Sciences*. **2022**, *12* (4), 227. https://doi.org/10.3390/educsci12040227

Zidny, R.; Sjöström, J.; Eilks, I. A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability. *Science and Education*. **2020**, *29* (1), 145–185. https://doi.org/10.1007/s11191-019-00100-x