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Assessing socio-scientific reasoning through local water issues: instrument development for preservice elementary teachers

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Abstract

The study aims to develop and validate a Socio-Scientific Reasoning (SSR) assessment instrument based on local water issues for preservice elementary teachers. The simplified Research and Development (R&D) method from the Borg & Gall model was used in this study. The development process includes three main stages: preliminary study, instrument development and Validation, and limited trials. The instrument was designed around six key dimensions of SSR and consists of 24 extended-response items, contextualized within a conflict over the distribution of Senjoyo springs in Semarang Regency. Content validation was done through expert review using Aiken's V, while empirical validity and reliability were tested using the Rasch model. The results showed that most questions were valid and reliable, with high internal consistency. The instrument trial with 108 preservice elementary school teachers showed that participants' SSR abilities varied, with the highest achievements in the inquiry and context-bound dimensions and the lowest in the skepticism and affordances of science and non-science considerations dimensions. This study emphasizes developing SSR instruments tailored to local contexts to support critical, reflective, and contextually grounded elementary science learning.

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1. Introduction

Today's global society faces complex challenges that intertwine science, social principles, culture, and public policy. Issues such as climate change, environmental degradation, natural resource management, renewable energy, and biotechnology remain pressing global concerns

(Deta et al., 2021; Owens et al., 2022; Susilowati et al., 2021). These problems are inherently complex, contextual, and multidimensional, requiring interdisciplinary approaches that integrate science with social and cultural values. Such problems are known as socio-scientific issues (SSI), which require individuals not only to understand scientific concepts but also to make ethical and responsible decisions in real-life contexts (Birmingham & Calabrese Barton, 2014; Schenk et al., 2021).

Socio-scientific reasoning (SSR) provides a framework that enables individuals to critically evaluate, analyze, and make informed, reflective decisions in the context of SSI (Romine et al., 2020). SSR is essential for preparing preservice elementary teachers to link science learning with real-world social and environmental challenges. This capability supports meaningful scientific literacy aligned with the principles of Education for Sustainable Development (ESD).

However, several challenges persist in fostering SSR skills among preservice elementary teachers. Many still focus primarily on conceptual and memorization aspects (Susilowati et al., 2021) and are not accustomed to addressing issues that require integration among science, social values, and culture. Additionally, the limited availability of valid, reliable, and contextually relevant assessment instruments hinders systematic efforts to measure and enhance SSR skills. Without standardized tools, educators and researchers struggle to monitor preservice teachers' skill development effectively (Wongwanich et al., 2024).

Although the SSR framework has been widely explored in previous studies (Owens et al., 2022; Romine et al., 2020), most research continues to focus on global issues such as climate change, nuclear energy, biotechnology, and vaccination. These instruments tend to be generic and overlook learners' socio-cultural diversity, thereby reducing their relevance in contexts involving local issues. Moreover, most SSR studies target high school or science-major students, with limited attention to preservice elementary teacher education (Kinskey & Zeidler, 2024; Orhan & Genç, 2024).

SSR was initially conceptualized in terms of four key dimensions: complexity, inquiry, perspective-taking, and skepticism (Sadler, 2011). While this framework provided a solid foundation for understanding socio-scientific reasoning, it has limitations in capturing the influence of local contexts on students' reasoning. (2022) expanded the model into five dimensions: complexity, inquiry, perspective-taking, skepticism, and the affordances of science and non-science considerations. This expansion acknowledges that SSIs can be approached from multiple perspectives, including scientific, cultural, and economic. To address the remaining gap in local contextual influences, this study further extends the model by incorporating an additional dimension —context-bound understanding —that emphasizes that socio-scientific issues and their scientific studies are inseparable from the local contexts in which they arise (Ruth Chadwick, 2019).

Local water issues represent socio-scientific issues that intertwine social and hydrological aspects and are particularly relevant for elementary science education. Topics such as water scarcity, pollution, flooding, drought, and conflicts over resource use provide authentic contexts for fostering critical thinking and sustainability-oriented learning (Kavita Krishna, 2021; Pablo A. Garcia-Chevesich1, two et al., 2023). This study, a local example, namely, the Senjoyo spring water distribution conflict in Semarang Regency, illustrates how hydrological challenges can evolve into social disputes involving competing needs among the community, agricultural, and industrial sectors. This case exemplifies the complex interconnection of social, economic, and environmental dimensions that make local water issues ideal for SSR-based learning and assessment (Levy & Moore Mensah, 2021).

Using local water issues as the main context for developing SSR instruments makes the assessment more contextual and relevant to the lives of preservice elementary school teachers. The local context, which is closely related to everyday life, helps them connect more deeply with the issue and motivates them to think critically and reflectively about possible solutions.

However, few SSR instruments have been developed specifically to address local issues. This indicates a gap in the international literature regarding the development of locally contextualized SSR assessments, particularly in the field of socio-hydrological issues familiar to communities. Instruments developed within local social and ecological contexts offer advantages over generic instruments that often rely on global or abstract issues.

Therefore, this study aims to develop and validate an SSR assessment instrument for preservice elementary teachers in the context of local water issues. This instrument is expected to provide more authentic insights into students'' reasoning skills and support the integration of socio-scientific and sustainability perspectives in teacher education.

2. Method

This study uses a research and development (R&D) approach with a development model that adapts the steps from Borg & Gall, which have been simplified into three main stages, namely preliminary studies and needs analysis, instrument development and Validation, and limited trials to see the reliability and practicality of the instrument (Amalia & Arthur, 2023). This study focuses on developing a Socio-Scientific Reasoning (SSR) assessment instrument based on local water issues.

2.1 Preliminary study and needs analysis

In the preliminary stage, a comprehensive review of the literature on SSR and local water issues was conducted. The research team analyzed existing SSR instruments to identify gaps in assessing socio-scientific reasoning within local contexts. In addition, needs analysis involved interviews with science education lecturers and a small group of preservice elementary teachers to determine the competencies and challenges related to SSR. This stage ensured the instrument would be relevant and aligned with preservice teachers' learning needs.

2.2 Instrument development and expert validation

The instrument was developed based on six key dimensions of SSR. Draft items were reviewed by five expert validators selected based on the following criteria: (1) expertise in science education, (2) a minimum of five years of professional experience in education, and (3) previous experience in developing or reviewing educational assessment instruments. Content validity was evaluated usingAiken's V, and revisions were made based on expert feedback. The development procedure is described in Figure 1 below.

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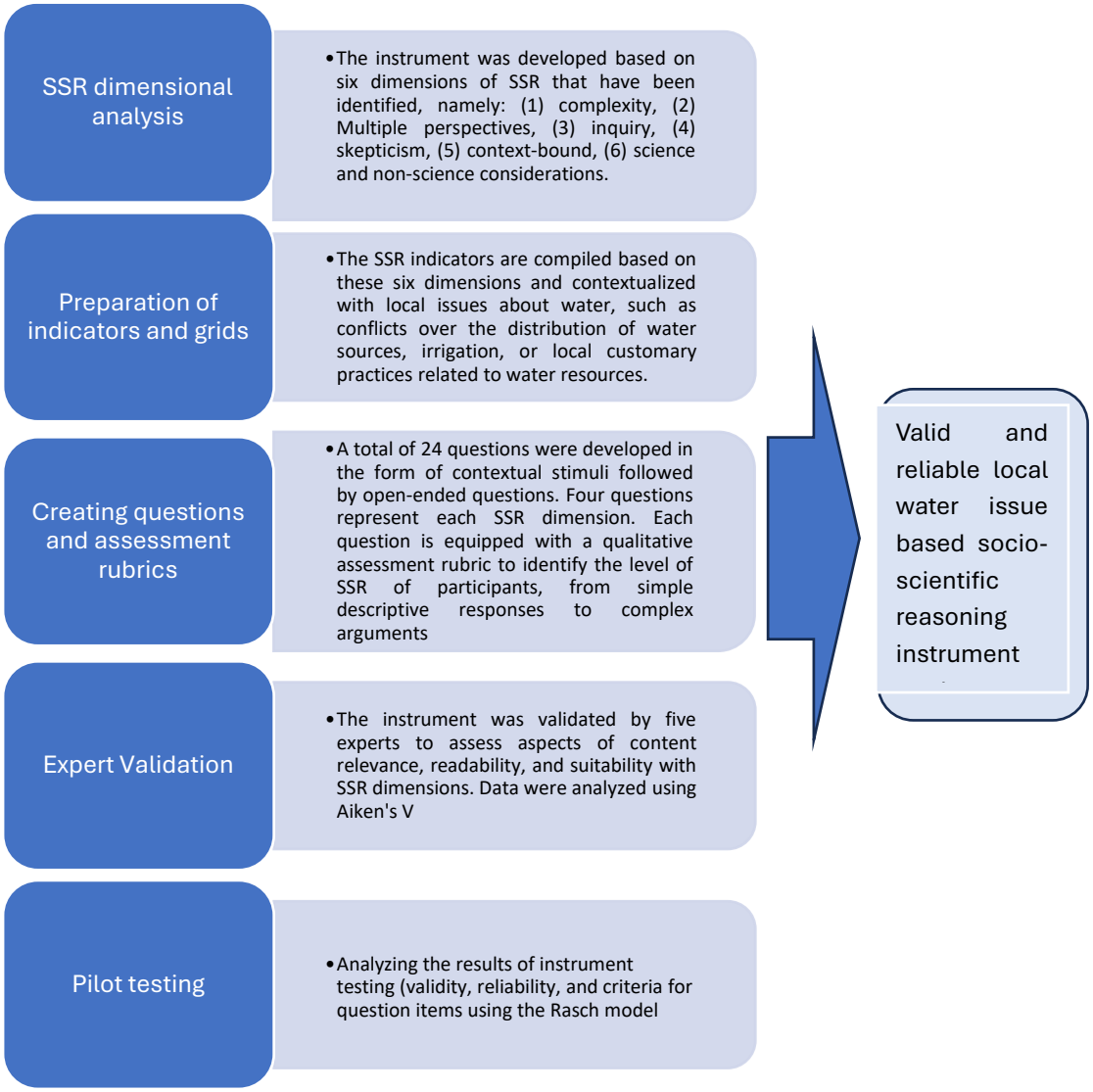

Figure 1. Steps for development and expert validation limited trial

The trial participants consisted of 108 preservice elementary school teachers from the Elementary School Teacher Education Program at Universitas Darul Ulum Islamic Centre Sudirman, Semarang, and Universitas Kristen Satya Wacana, Salatiga. They were in their second semester and had completed the Basic Science Concepts course, which equipped them with foundational knowledge relevant to the instrument's content. This group was selected to represent preservice teachers with sufficient pedagogical and conceptual backgrounds to respond appropriately to SSR assessments. This instrument, consisting of 24 extended-response items, was administered via a Google form with clear instructions. The trial results were then scored and analyzed for validity, reliability, and test-item characteristics using the Rasch Model, with the Winstep version 5.7.3.0 application, to determine the instrument's feasibility. Local independence and parameter invariance are used to analyze test item characteristics using unidimensional parameter testing. The output from the WINSTEPS application was then interpreted to determine valid test items, the level of instrument reliability, and the characteristics of test items. The selection of valid test items was based on examining the outfit Mean Square (MNSQ), Z-standard Outfit (ZSTD), and outfit Point Value Correlation (PT mean corr)

values. Instrument items are declared valid if they meet at least two acceptance criteria in Table 1.

Table 1. Question item validity criteria

No	Reference	Limit Value
1	*Outfit mean square* (MNSQ)	0.5 < MNSQ < 1.5
2	*Outfit Z-standard* (ZSTD)	-2.0 < ZSTD < +2.0
3	*Point measure correlation* (pt mean corr)	0.4 < Pt Mean Corr < 0.85

(Loi et al., 2016).

Measurement of instrument reliability also uses criteria based on the Cronbach's alpha coefficient in Table 2, which is adjusted to the reliability figures from the Rasch analysis results (Boone, 2016).

Table 2. The classification of cronbach's alpha coefficient

Cronbach's Alpha Coefficient	Interpretation
< 0.5	The scale has no internal consistency.
$0.5 - 0.6$	The scale's internal consistency is weak.
$0.6 - 0.7$	The scale's internal consistency is acceptable.
$0.7 - 0.8$	The scale has internal consistency.
> 0.8	The scale's internal consistency is very high.

3. Results

3.1 Suitability of the instrument to the objectives and dimensions of the SSR

The instrument was developed to assess the socio-scientific reasoning ability of prospective elementary school teachers, particularly when confronting real-world issues in the community, such as local water issues. The six dimensions of SSR served as the core reference for developing indicators and questions. In each dimension, there were two indicators, and each indicator was further developed into two questions. The instrument developed in this study consisted of 24 questions in the form of an extended-response test based on local issues related to the distribution conflict of the Senjoyo spring in Semarang Regency. The questions were designed to measure each indicator of the six dimensions of Socio-Scientific Reasoning (SSR), namely: (1) complexity, (2) Multiple perspectives, (3) inquiry, (4) skepticism, (5) context-bound, (6) science and non-science considerations.

The instrument developed to measure prospective elementary school teachers' SSR abilities has undergone a content validation process by five experts. The results of Aiken's V calculation indicate that, in general, the instrument's items are highly suitable for the objectives and six dimensions of SSR that serve as the basis for development. Of the total 24 questions, 19 items (79%) had an Aiken's V value of ≥ 0.80, indicating a high level of agreement (Nurjanah et al., 2023) among experts regarding the relevance of each item to the SSR dimension indicators being measured. The items with the highest value (V = 0.95) come from the multiple perspectives, context-bound, and complexity dimensions, which indicate that the scenarios and questions prepared have been able to stimulate prospective elementary school teachers to consider the diversity of perspectives, complexity of factors, and the attachment of local contexts in solving issues.

Table 3. Results of aiken's v analysis for content validity from experts

Validity Status	Number of Questions	Value Range	Question Number
Valid (V ≥ 0.80)	19 Questions	0.80 – 0.95	1,2,3,4,5,7,8,9,11,12,14,15,16,17,18,20,21,22,23
Needs minor revision (0.70 ≤ V < 0.80)	4 Questions	0.70 – 0.75	6,10,13,19
Needs Major Revision / Removed (V < 0,70)	1 Questions	0.60	24

On the other hand, four questions scored between 0.70 and 0.75: 6, 10, 13, and 19. These items address the dimensions of skepticism, inquiry, and science vs. non-science considerations and require special attention. Aiken's V value in this range indicates that several experts consider the questions to still not fully represent the intended indicators, both in terms of stimulus, wording, and the cognitive focus built. For example, question 13, which measures skepticism towards scientific information, scored a V value of 0.70. This indicates a need to improve to encourage participants to think critically about claims and data. In addition, one question (question 24) scored an Aiken's V value of 0.60 and was below the minimum eligibility limit (0.70). This indicates that the item does not sufficiently represent the SSR dimension by most validators. It is recommended that this question be revised thoroughly or removed from the instrument at the finalization stage.

3.2 Empirical validity and reliability of questions

After the question indicators were created, the test questions were developed as an extended-response test comprising 24 questions. The trial results were analyzed using the Rasch model.

Table 4. Results of the content validity test

No.	Item Code	Infit MNSQ	Outfit MNSQ	ZSTD Infit	PTMEASUR CORR	Information
1	S1	1.20	1.51	1.32	-0.11	Still within tolerance limits
2	S2	1.00	0.99	0.06	0.72	Very fit
3	S3	1.22	1.46	1.46	-0.14	Approaching the upper limit
4	S4	1.09	1.12	0.61	0.58	Fit
5	S5	1.17	1.37	1.14	-0.08	Fit
6	S6	1.05	1.07	0.41	0.64	Fit
7	S7	0.91	0.89	-0.64	0.60	Fit
8	S8	0.97	0.96	-0.20	0.67	Fit
9	S9	1.16	1.22	1.03	0.59	Fit
10	S10	0.85	0.83	-1.15	0.53	Fit
11	S11	1.07	1.03	0.56	0.71	Fit
12	S12	1.14	1.25	0.97	0.01	Fit
13	S13	1.18	1.32	1.19	0.49	Fit
14	S14	0.94	0.93	-0.46	0.62	Fit
15	S15	0.89	0.86	-0.82	0.66	Fit
16	S16	0.92	0.90	-0.59	0.68	Fit

No.	Item Code	Infit MNSQ	Outfit MNSQ	ZSTD Infit	PTMEASUR CORR	Information
17	S17	1.11	1.09	0.78	0.70	Fit
18	S18	0.99	1.00	0.02	0.74	Very fit
19	S19	1.04	1.05	0.35	0.69	Fit
20	S20	1.03	1.01	0.30	0.78	Very fit
21	S21	0.93	1.01	-0.50	0.63	Fit
22	S22	1.09	1.13	0.65	0.57	Fit
23	S23	0.97	0.96	-0.21	0.71	Fit
24	S24	0.95	0.94	-0.40	0.61	Fit

Empirical validity analysis was conducted using the Rasch model with the help of Winsteps 5.7.3 software. The data processing results on 24 items showed that most items were within the range of values that were by the criteria for the suitability of the Rasch model. Specifically, the Infit and Outfit Mean Squares (MNSQ) values for most items were within the recommended range of 0.5 and 1.5 (Maria et al., 2025). For example, item S1 has an Infit MNSQ of 1.20 and an Outfit MNSQ of 1.51, while item S3 has an Infit value of 1.22 and an Outfit of 1.46. Although the values on these items are close to the upper limit, both can still be considered by the model (fit), especially since the ZSTD value is still within the range of ±2.

In addition, most items' Z-standardized (ZSTD) values are also from -2 to +2, indicating no significant deviation from the model prediction. For example, item s5 has a ZSTD of 1.14, and item s12 is 0.97. The correlation between item scores and ability estimates (Point-Measure Correlation) also shows a positive, adequate result. The PTMEASUR CORR values range from 0.27 to 0.78, indicating that these items positively contribute to measuring respondents' socio-scientific reasoning (SSR) abilities.

Therefore, it can be concluded that, in general, all items are in the fit category of the Rasch model, and no items need to be eliminated based on statistical criteria. These results indicate that the instrument has adequate construct validity and can accurately and consistently measure SSR abilities in prospective elementary school teachers.

3.3 Reliability

The reliability analysis results show that the instrument has a Person Reliability of 0.89 (Real) and 0.90 (Model), and an Item Reliability of 0.98. This value indicates a very high level of measurement consistency. In addition, the separation values of 2.92 for person and 7.51 for item indicate the instrument's ability to distinguish among various levels of respondent ability and the stability of item estimates. The Cronbach's Alpha value of 0.90 also strengthens the finding that this instrument has high internal reliability (Taber, 2018) in measuring the Socio-Scientific Reasoning (SSR) construct in prospective elementary school teachers.

Table 5. Summary of rasch reliability statistics

Statistic	Person	Item
Reliability (Real)	0.89	0.98
Reliability (Model)	0.90	0.98
Separation	2.92	7.51
Cronbach's Alpha	0.90	–
Infit MNSQ Range	0.81 – 1.22	0.81 – 1.22

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Statistic	Person	Item
Outfit MNSQ Range	0.80 – 1.51	0.80 – 1.51
ZSTD Range	-1.52 – 2.78	-1.52 – 2.78

The validity and reliability results above indicate that the developed instrument meets the criteria for construct validity and has excellent internal reliability. Therefore, this instrument is suitable for measuring the Socio-Scientific Reasoning ability of prospective elementary school teachers, both for research purposes and as a learning evaluation tool.

Based on the expert validity and empirical analysis results, 12 questions were selected to represent the six dimensions and 12 indicators of socio-scientific reasoning. These items constitute the final version of the SSR instrument, which is feasible and ready to use for assessing preservice elementary teachers'' socio-scientific reasoning skills.

4. Discussion

The discussion of the findings focuses on how the developed instrument represents the six dimensions of socio-scientific reasoning (SSR) within the context of a local water issue. Based on the research results, each indicator was represented by a single highly valid question. This result indicates that most of the instrument items are highly suitable for the theoretical construct of SSR, especially when integrated with the local water issue, namely the conflict over the distribution of the Senjoyo spring in Semarang Regency. High content validity enhances the reliability of this instrument in evaluating preservice elementary teachers' socio-scientific reasoning abilities in addressing complex, value-laden socio-hydrological issues.

Based on the results of the expert validity analysis and the empirical assessment of validity and reliability using the Rasch model, an extended-response test on local water issues was developed into a ready-to-use instrument, as presented in Table 6 below. Before presenting the questions, students were given a narrative about the local water issue and the emerging conflicts, along with existing data. After that, the extended-response test questions were presented using the following grid.

Table 6. Final socio-scientific reasoning instrument

No	Dimensions	Indicator	Question
1.	Complexity	1. Able to identify various factors that influence local water issues, including social, cultural, economic, and environmental aspects.	1. Identify and describe the various factors that influence the conflict over the distribution of water sources, including social, cultural, economic, and environmental aspects.
		2. Able to analyze several alternative solutions for local water issues by considering each alternative's benefits, costs, and impacts.	2. Create alternative solutions, then analyze them to overcome the conflict over the distribution of water sources, considering the proposed solutions' benefits, costs, and impacts.
2.	Ongoing inquiry	1. Able to identify aspects of local water issues that require additional data or information to understand.	1. What information is still lacking or needs further investigation to understand the water issues there?
		2. Able to identify potential further research for decision-making related to local water issues.	2. In your opinion, what research or studies still need to be carried out so that decision-making regarding water management can be more appropriate and fair?

No	Dimensions	Indicator	Question
3.	Multiple perspectives	1. Able to identify various stakeholders involved in local water issues and understand their respective roles and interests.	1. In the water conflict in Sendang Senjoyo, who do you think are the parties involved? Explain what their roles are and what interests they bring to this issue.
		2. Demonstrating the ability to detail how the perspectives of various stakeholders can influence decisions or actions taken in the context of local water issues.	2. In the case of water in Sendang Senjoyo, how can each party's perspectives influence the decisions or actions taken? Explain with examples.
4.	Skepticism	1. Identify potential bias in the information provided and refer to factors that may cause it, such as specific sources or points of view.	1. In the case of Sendang Senjoyo, is there any information that feels biased? In your opinion, what is the cause, and from whose perspective?
		2. Able to compare information from several sources and assess which is the most reliable based on the source's credibility or the author's reputation.	2. When you read the Sendang Senjoyo case from several sources, how do you judge which information is the most reliable? What are your considerations?
5.	context-bound.	1. Be able to identify and describe the social, cultural, and environmental contexts that influence local water issues and how these contexts shape the problems and proposed solutions.	1. In the case of Sendang Senjoyo, how do you think the social, cultural, and environmental contexts shape the water problem there? Also, explain how they influence possible solutions.
		2. Able to provide concrete examples of how local water issues in one place or time can be handled differently from other places or times due to differences in social and cultural contexts.	2. In your opinion, would handling water problems like those in Sendang Senjoyo be the same if they occurred in another place or at another time? Give an example that shows how social or cultural differences can affect how they are handled.
6.	Affordances of science and non-science considerations	1. Be able to explain how scientific and non-scientific considerations interact and influence each other in formulating solutions to local water issues.	1. In the case of Sendang Senjoyo, how do you think scientific considerations (such as water discharge data) and non-scientific considerations (such as cultural values or economic interests) influence each other in finding a solution? Explain with examples.
		2. Able to formulate solution recommendations that consider the balance between scientific research results and social and cultural implications for local or global communities.	2. Based on the Sendang Senjoyo case, propose a solution that you think is balanced between the results of scientific studies and their impact on the social and cultural life of the community. Explain your reasons.

The description of the suitability of the instrument with the objectives and indicators of SSR is as follows:

4.1 Dimension of complexity. The ability to understand Complexity in SSI can be seen from how students emphasize the multifaceted nature of the problem being analyzed (Norman G. Lederman, Dana L. Zeidler, 2023). The question presents a scenario regarding the need for agricultural irrigation and water distribution from uneven water sources monopolized by large companies, ultimately leading to conflict. Student responses showed that the majority could identify more than one interrelated factor: community water needs, agricultural sustainability, and environmental impacts. This indicates that the question effectively explores participants' ability to appreciate the problem's complexity.

4.2 Multiple perspective dimension.The Multiple perspective dimension in SSI includes ethics, sociology, economics, environment, science, and policy, helping students understand SSI holistically (Ghairat, 2013). The question asks prospective elementary school teachers to consider the views of four different parties: farmers, large companies that use water sources, local governments, and local communities. From the response analysis, 68% of participants could mention at least two different perspectives and explain the differences in interests between the parties. This shows that the question successfully measures participants' ability to understand and compare various points of view.

4.3 The dimension of skepticism about information is revealed through questions that insert information from various sources (Ben-Horin, 2023), such as news sources, local government data releases, and scientific journal articles related to the water source. As many as 48% of participants showed a critical attitude towards the validity and potential bias of the information, asking questions such as "Who published this data?" and "What are the interests of the party conveying the information?" This reflects the emergence of critical thinking skills and awareness of information bias.

4.4 Inquiry dimension. Prospective elementary school teachers with SSR competency should actively seek additional information rather than stop at the initial knowledge available (Irmak, 2020; Nugroho et al., 2024). The question asked prospective elementary school teachers to propose additional questions about the causes of the decrease in spring discharge, which was a source of conflict. As many as 72% of participants could ask questions that explored ecological and social aspects, such as "What caused the decrease in water discharge in the last five years?" or "Do changes in land use affect the sustainability of springs?" This shows that the question succeeded in encouraging participants to recognize the importance of further scientific investigation to understand the problem's complexity.

4.5 Context-bound dimension. The questions present scenarios that link water management to local geographic and cultural conditions, such as the tradition of rotating water distribution in the area. Participant responses showed that 79% of prospective elementary school teachers could recognize the connection between the solutions offered and the specific local context. For example, several participants emphasized the importance of considering the long dry season, the contours of upstream and downstream areas, and the community's cooperative water management practices. This shows that participants understand that scientific issues cannot be separated from the local context, and that practical solutions must be adapted to local conditions (Alat et al., 2023).

4.6 Dimension of science and non-science considerations. The questions present solutions based on technical data, non-scientific considerations such as community beliefs about water as a source of life, and local economic factors. From the participants' responses, 46% indicated awareness of the need to consider both scientific and non-scientific aspects in decision-making. Several students stated that "the data presented is important, but not enough if it does not consider the culture of the community that depends on the water

source." This shows that the instrument can stimulate participants' understanding that socio-scientific issues require synthesizing scientific facts and social values (Owens et al., 2022)

In general, the analysis results show that the instrument questions reveal various forms of students' socio-scientific reasoning across the SSR dimensions. The integration of authentic local contexts with question structures based on SSR dimensions provides the strength of this instrument in assessing complex competencies.

Analysis of preservice elementary teachers' responses to questions about the Senjoyo spring distribution conflict reveals variations in their SSR abilities. Most of them generally demonstrate SSR abilities at the descriptive to intermediate level, especially in dimensions that require direct identification of information, such as those involving context-bound and multiple perspectives. Interestingly, only a few preservice elementary teachers can develop complex and reflective arguments, particularly in areas such as complexity, inquiry, skepticism, and the interplay between science and non-science considerations.

In the complexity dimension, 61% of prospective elementary school teachers could only identify one leading cause of conflict, such as corporate domination of water sources. Their responses did not yet demonstrate a deep understanding of the interconnectedness of factors such as governance, regulation, and differences in access between community groups. Only about 18% of participants could link several factors and consider the consequences of their relationships.

In the inquiry dimension, approximately 72% of prospective elementary school teachers demonstrated the ability to ask follow-up questions on the given issues. This suggests potential for scientific thinking. However, most of the questions are still factual, not leading to exploration of cause-and-effect relationships or alternative solutions. In the multiple perspectives dimension, 68% of prospective elementary school teachers could identify at least 2 different points of view in water conflicts, such as between residents and private companies. However, analyzing conflicts of interest among parties remains limited to general descriptions. The analysis has not shown an understanding of the background values and potential tensions between parties.

Most prospective elementary school teachers had difficulty critically evaluating information in the skepticism dimension. Only about 48% of participants showed skepticism towards the validity of the information source or the potential bias in the data provided. Most prospective teacher students tended to accept information as it is, without questioning the information maker's credibility or point of view. In the context-bound dimension, prospective elementary school teachers showed relatively good achievements. Around 79% of participants could relate the issue of water distribution to the local context, including the needs of village communities, agricultural systems, and the community's cultural values around the Senjoyo spring. However, in-depth explanations of how the local context influences the solutions offered remain limited.

Students achieved high scores on the context-bound dimension because the issues used in the SSR instrument stem from local contexts that are close to their own experiences. These include issues such as water distribution, agricultural irrigation, and cultural practices of spring water management in surrounding communities. This proximity facilitates students' understanding of the relationship between the scientific and social aspects of the issues at hand, enabling them to reason more contextually. Furthermore, exposure to real-life experiences and local cultural values strengthens their ability to connect scientific knowledge to relevant socio-ecological realities.

In the affordances of science and non-science considerations dimension, most prospective elementary school teachers were unable to distinguish between scientific and non-scientific factors. Only about 46% of participants could explicitly analyze the advantages and limitations of the scientific approach compared to other approaches in understanding and resolving water conflicts.

These findings suggest that the observed weaknesses in specific SSR dimensions — particularly skepticism, complexity, and the integration of science and non-science considerations — may be influenced by several factors. First, prospective elementary school teachers are generally more accustomed to receiving information passively in their previous learning experiences, which often emphasize memorization over critical evaluation. As a result, they may lack sufficient practice in questioning the credibility of sources or identifying potential biases in information. Second, the complexity of socio-hydrological issues, which intertwines scientific, social, cultural, and economic factors, may pose cognitive challenges for students with limited exposure to such multifaceted problems.

Furthermore, the low performance in skepticism and complex reasoning could also be linked to the predominantly theoretical or abstract nature of previous SSI topics studied at the preservice level. Localized issues, like the Senjoyo spring conflict, require students to connect scientific knowledge with contextual social and cultural values, a skill that may not have been adequately developed in conventional science education. Research conducted by Sari et al. (2025) and Darta Putra et al. (2025) recommends the development of a science learning model that combines local wisdom, such as the Toba Nauli philosophy and the Baganduang boat value, as a foundation for the local context to improve students' science literacy in a meaningful, contextual, and culturally rooted manner. Similar research was also conducted by Suarmika & Hidayat (2023), who found that student engagement in learning is higher when the science learning model is integrated with indigenous science as a context. These factors underscore the importance of incorporating authentic, context-rich scenarios into teacher education to foster more profound socio-scientific reasoning and critical thinking skills.

Developing a Socio-Scientific Reasoning (SSR) instrument based on local water issues has significant implications for increasing prospective teachers' readiness to integrate SSI into science learning in elementary schools. This instrument not only serves as a measurement tool but also as a learning tool that can encourage prospective teachers to better understand the characteristics of SSI. By raising local water issues, this instrument allows prospective teachers to practice recognizing, understanding, and responding to various dimensions of SSR. Using relevant contexts can increase prospective teachers' readiness to apply SSI in the classroom (Klijnstra et al., 2024). Reviewing SSR questions will make prospective teachers understand in detail the SSR abilities that need to be developed in learning SSI. This will contribute to prospective teachers' critical awareness of the importance of linking science learning to students' real lives by integrating SSI into learning. Therefore, a holistic approach to elementary school teacher education is needed, involving SSI (Kinskey & Newton, 2024).

The use of local issues, especially conflicts over the distribution of water sources in certain areas, in developing SSR instruments has been shown to provide high contextuality and cultural relevance for prospective teachers. The local environmental context significantly shapes SSR patterns (Tekin, 2024). Local issues are close to their daily lives and reflect the fundamental dynamics of the communities they live in. Issues such as conflicts over water access between residents and corporations, and tensions between modernization and local wisdom, such as the Gilir guling tradition, significantly shape prospective teachers' SSR abilities.

The local context encourages students to think more concretely and reflectively. This is because they can connect the problem scenario with the experiences around them. This can be seen in the students' answers, which include the name of the region, the local irrigation system, and the community's experience in managing water from generation to generation. Local issues

are considered more relevant and motivating than global ones (Matthiesen et al., 2024). The SSR instrument intended for prospective elementary school teachers ideally includes items related to understanding contextual NOS in the form of local issues, with relevant provisions to develop SSR in their students in the future (Qu, 2023; Rahayu et al., 2024). Thus, the instrument measures prospective elementary school teachers' SSR abilities and opens space for their affective dimensions and social identities as prospective teachers who will teach in the local community.

Compared to previous research, most studies on Socio-Scientific Reasoning still use global or national issues, such as general environmental (Chang et al., 2018), Social justice (Macalalag et al., 2024), the earth water system (Owens et al., 2022), climate change(Septi et al., 2024), or genetic engineering(Viehmann et al., 2024). Although these issues are important, their relevance to students' lives is often abstract or too distant from local reality. This results in responses that tend to be theoretical or not fully reflect understanding based on real experiences. This local water issue approach helps prospective elementary school teachers develop SSR and prepares them to become learning facilitators sensitive to local needs and values.

This study contributes to the development of SSR measurement instruments tailored to local issues, but several limitations must be acknowledged. First, the number of participants in this study is still limited; it only involves prospective teacher students from one study program at two universities. This limits the generalizability of the results to a broader population. To gain a more comprehensive understanding of the SSR abilities of prospective elementary school teachers in Indonesia, further research is needed that involves participants from various institutions and regions with diverse socio-cultural contexts and local issues.

The findings and limitations of this study open up opportunities for future research, both in terms of the instruments and their implementation in the education of prospective elementary school teachers. First, the SSR instrument needs to be further developed into a quantitative form that can be tested widely and that would make the analysis more efficient. It is necessary to convert the instrument into a multiple-choice format, either based on scenarios or Likert scales, while maintaining the complexity of the SSR's context and dimensions. Second, the SSR instrument, developed based on the local water issue, has the potential to be used in intervention research, especially to evaluate the effectiveness of SSI-based learning. Further research can use the instrument to measure students' SSR abilities before and after the intervention. The study not only tests the instrument's accuracy in detecting changes but also assesses the effectiveness of the SSI teaching strategy.

5. Conclusion.

This study developed and validated a Socio-Scientific Reasoning (SSR) instrument based on local water issues for preservice elementary school teachers. The instrument covers six SSR dimensions: complexity, inquiry, multiple perspectives, skepticism, context-bound reasoning, and science versus non-science considerations. Expert Validation and Rasch analysis confirmed its high relevance, reliability, and validity. By using a local water issue as the context, this instrument can serve as a model for developing context-sensitive assessments in other regions of Indonesia. Such assessments can more effectively support Education for Sustainable Development by providing authentic evaluations aligned with local realities. Future research can expand its use through quantitative studies and cross-context interventions.

Credit authorship contribution statement

First Author: Conceptualization, Formal analysis, Data curation, **Second Author**: Methodology, **Third Author:** Methodology, Data curation, **Last Author**: Data curation, Literature searcher

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