

DEVELOPMENT AND CONTENT VALIDATION OF A SOCIOSCIENTIFIC PROBLEM-SOLVING SKILLS INSTRUMENT IN BIOLOGY EDUCATION: AN ANIMAL CONSERVATION CONTEXT

PENGEMBANGAN DAN VALIDASI ISI INSTRUMEN KETERAMPILAN PEMECAHAN MASALAH SOSIO-ILMIAH DALAM PENDIDIKAN BIOLOGI: PADA KONTEKS KONSERVASI HEWAN

Anwari Adi Nugroho^{1*)}, Suwarto²⁾, Agus Purwanto³⁾, Hemalia Susanti⁴⁾, Tyas indriasari⁵⁾, Alem Abdildaully⁶⁾

^{1*)}, ²⁾, ³⁾, ⁴⁾, ⁵⁾ Biology Education, Faculty of Teacher Training and Education, Universitas Veteran Bangun Nusantara, Sukoharjo, Indonesia, email: ^{1*)}anwaribio@gmail.com (correspondence author),

²⁾suwartowarto@yahoo.com, ³⁾purwantoaguss183@gmail.com, ⁴⁾hemaliasusanti@gmail.com,

⁵⁾tyasindriasari@gmail.com

⁶⁾ Zhetysu University named after I. Zhansugurov, Taldykorgan, Republic of Kazakhstan, email:

⁶⁾alem.abdildaully@gmail.com

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Abstract

This study aimed to develop and establish the content validity of a Socioscientific Problem-Solving Skills (SSPS) instrument for biology education in the context of animal conservation. A research and development design was employed using a modified Delphi method. The instrument integrates four socioscientific issue (SSI) components scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty with four problem-solving dimensions. Ten experts evaluated the instrument, and data were analyzed using Aiken's V coefficient. The instrument comprises eight open-ended essay items representing four SSPS dimensions. After one round of expert evaluation and refinement, all items met acceptable content validity criteria, with Aiken's V coefficients ranging from 0.78 to 1.00 across five validation aspects. Minor revisions were made to construct alignment and contextual representation based on qualitative expert feedback. These findings indicate that the instrument is conceptually grounded and multidimensional, with adequate content validity for assessing cognitive and socio-ethical aspects of problem solving in animal conservation contexts. The study was limited to expert-based content validation and did not include empirical testing with students. Further empirical validation is needed to examine its construct validity and reliability, particularly among pre-service biology teachers. The instrument provides a framework for integrating SSI and problem-solving in biology education.

Keywords: animal conservation, instrument, socioscientific, validity, problem solving

Abstrak

Penelitian ini bertujuan untuk mengembangkan dan memvalidasi isi instrumen Keterampilan Pemecahan Masalah Sosiosaintifik (SSPS) untuk pendidikan biologi dalam konteks konservasi hewan. Penelitian menggunakan desain penelitian dan pengembangan dengan metode Delphi yang dimodifikasi. Instrumen mengintegrasikan empat komponen isu sosiosaintifik (SSI), yaitu bukti ilmiah, penalaran moral, perspektif pemangku kepentingan, dan ketidakpastian, dengan empat dimensi pemecahan masalah. Sebanyak 10 pakar mengevaluasi instrumen, dan data dianalisis menggunakan koefisien V Aiken. Instrumen terdiri atas delapan butir soal esai terbuka yang merepresentasikan empat dimensi SSPS. Setelah satu putaran evaluasi dan penyempurnaan oleh pakar, seluruh butir memenuhi kriteria validitas isi yang dapat diterima, dengan nilai V Aiken berkisar antara 0,78 hingga 1,00 pada lima aspek validasi. Revisi minor dilakukan pada keselarasan konstruk dan representasi konteks berdasarkan umpan balik kualitatif dari pakar. Temuan menunjukkan bahwa instrumen memiliki landasan konseptual yang kuat dan bersifat multidimensional, dengan validitas isi yang memadai untuk mengukur aspek kognitif dan sosio-etis dalam pemecahan masalah pada konteks konservasi hewan. Penelitian ini terbatas pada validasi isi berbasis penilaian pakar dan belum mencakup pengujian empiris pada mahasiswa. Validasi empiris lebih lanjut diperlukan untuk menguji validitas konstruk dan reliabilitas instrumen, khususnya pada calon guru biologi. Instrumen ini menyediakan kerangka untuk mengintegrasikan SSI dan pemecahan masalah dalam pendidikan biologi.

Katakunci: konservasi hewan, instrumen, sosiosaintifik, validitas, pemecahan masalah

Introduction

Socioscientific issues (SSI) have increasingly become a central focus in science education due to their potential to connect scientific knowledge with real-world contexts. SSI typically involve complex and open-ended problems that require individuals to consider not only scientific evidence but also ethical, social, and environmental dimensions (Högström et al., 2024; Viehmann et al., 2024; Zeidler et al., 2019). Therefore, SSI-based learning is widely regarded as an effective approach to fostering students' scientific literacy and preparing them to make responsible decisions in society (Chen & Xiao, 2021; Sadler et al., 2016). Within this perspective, SSI function not merely as a learning context but also as a medium for developing higher-order and integrative thinking skills.

In the context of biology education, socioscientific issues such as biodiversity loss, climate change, and wildlife conservation are highly relevant as they are closely related to both global challenges and students' everyday experiences. These issues provide authentic contexts that encourage students to engage in higher-order thinking processes, including analysis, evaluation, and synthesis of information (Presley et al., 2013; Viehmann et al., 2024). The integration of SSI into biology learning has been shown to enhance students' ability to understand complex systems and apply scientific knowledge in solving real-world problems (Chen & Xiao, 2021; Evagorou et al., 2017; Friedrichsen et al., 2016).

To effectively engage with such issues, students need to develop socioscientific problem-solving skills (SSPS). Theoretically, SSPS can be conceptualized as a multidimensional construct encompassing several key processes, including problem identification, information analysis, evaluation of alternative solutions, and decision-making based on scientific and social considerations (Chen & Xiao, 2021; Christenson et al., 2012; Zeidler et al., 2019). This framework aligns with the concept of ill-

structured problem solving, in which problems do not have a single correct answer and require the integration of diverse forms of knowledge and values. Consequently, the assessment of SSPS must be capable of capturing the complexity and integrative nature of these cognitive processes.

From a broader theoretical perspective, SSPS are closely related to several key constructs in science education, such as scientific argumentation, critical thinking, and decision-making. Scientific argumentation emphasizes the ability to construct and evaluate claims based on evidence and reasoning (Jacobs et al., 2022; Nida et al., 2020; Smit et al., 2025), while critical thinking involves reflective evaluation of information and the identification of bias (Dusturia et al., 2024; Facione, 2015). Decision-making in socioscientific contexts, on the other hand, requires individuals to consider multiple perspectives, including scientific, social, and ethical dimensions (Fang et al., 2019; Sakamoto et al., 2021). Together, these constructs form a conceptual foundation that positions SSPS as an integrated higher-order skill essential for 21st-century learning (Kumar et al., 2024; Sari et al., 2024).

Consistent with this theoretical framework, a growing body of empirical research has highlighted the importance of developing socioscientific competencies in science classrooms. Previous studies have explored various instructional approaches, such as inquiry-based learning (Ariza et al., 2021; Nugroho et al., 2025; Qamariyah et al., 2021), argumentation-based learning (Arslan & Tüysüz, 2023; Güler & Şengül, 2023; Karaman & Aylin, 2025), and problem-based learning (Arthamena et al., 2025; Durak & Sami, 2025; Khasanah et al., 2025; Purnamasari et al., 2025), to enhance students' engagement with socioscientific issues. However, most of these studies primarily focus on instructional interventions, while the development of assessment instruments capable of validly

measuring SSPS remains relatively underexplored.

This limitation indicates a gap between instructional development and assessment practices. Existing instruments often measure related constructs, such as argumentation or decision-making, in isolation, rather than capturing the integrated nature of socioscientific problem-solving (Christenson & Walan, 2023; Irwanto et al., 2022; Mustika et al., 2025; Utami et al., 2024). Furthermore, only a limited number of instruments have undergone rigorous validation procedures, such as content validation through expert judgment, which is essential to ensure alignment between theoretical constructs and measurable indicators (Hartelt & Martens, 2025; Mansur & Manaf, 2023).

In addition, the lack of contextual specificity represents another critical limitation in existing assessment instruments. In particular, the domain of animal ecology and conservation has not been sufficiently represented, despite its strong relevance as a socioscientific context. Animal conservation issues inherently involve complex interactions among ecological, social, and ethical dimensions (Edelblutte et al., 2022; Luan et al., 2018), making them highly suitable for operationalizing SSPS. Within the conceptual framework of this study, animal conservation is employed as a contextual basis for translating the SSPS construct into measurable indicators. This approach enhances the ecological validity of the instrument by situating assessment within authentic and meaningful contexts.

Furthermore, animal conservation provides an authentic and educationally meaningful socioscientific context for biology teacher education, particularly in biodiversity-rich countries such as Indonesia. Indonesia is recognized as one of the world's megadiverse countries and faces persistent conservation challenges, including habitat loss, illegal wildlife trade, and increasing human wildlife conflicts, all of which threaten many endemic animal species (Eryan, 2024). These challenges involve not only ecological considerations but also ethical dilemmas, socio-economic interests, and policy decisions, making them highly appropriate socioscientific issues for biology education. For pre-service biology teachers,

engaging with local animal conservation issues enables them to connect biological concepts with scientific evidence, ethical reasoning, and responsible decision-making in contexts that are directly relevant to their future professional practice. Recent studies in Indonesia also emphasize that SSI-based instruction is essential for preparing biology teachers, yet they continue to face challenges in integrating authentic local contexts and assessing students' socioscientific competencies effectively (Faisal et al., 2025). Therefore, despite the educational importance of local biodiversity conservation, assessment instruments specifically designed to measure socioscientific problem-solving skills within Indonesian animal conservation contexts remain scarce. Developing a valid SSPS instrument grounded in authentic local conservation issues is therefore essential to provide contextually relevant assessment and to better prepare future biology teachers to promote biodiversity conservation through scientifically informed and socially responsible decision-making (Faisal & Martin, 2022).

Preliminary observations involving 30 biology education students at Universitas Veteran Bangun Nusantara revealed that most students experienced difficulties in analyzing authentic animal conservation issues. More than two-thirds of the students were unable to justify their proposed solutions using appropriate scientific evidence and tended to overlook ethical considerations and stakeholder perspectives during classroom discussions. Although these observations suggest challenges in socioscientific problem solving, they do not represent a formal assessment of students' SSPS because no validated instrument specifically designed for this purpose is currently available. This limitation further underscores the need to develop a valid and reliable SSPS assessment instrument. Establishing such an instrument is an essential prerequisite for accurately measuring students' competencies and for evaluating the effectiveness of future instructional interventions aimed at improving socioscientific problem-solving skills.

Moreover, the development of the SSPS instrument in this study is grounded in a clearly defined conceptual framework that integrates both socioscientific reasoning components and problem-solving processes. Specifically, the instrument is structured around four core components of socioscientific issues, namely scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty. These components represent the essential dimensions required for engaging with complex socioscientific problems (Jacobs et al., 2022; Lacorte, 2025; Sadler, 2011; Zeidler et al., 2019). In addition, the instrument operationalizes problem-solving skills through four sequential dimensions: defining the problem within an SSI context, exploring the problem through information analysis, planning solutions based on integrated considerations, and reflecting on and evaluating the proposed solutions (Nugroho et al., 2025; OECD, 2019). By combining these components and dimensions, the instrument is designed to capture the multidimensional and iterative nature of socioscientific problem-solving. These integrated constructs are further aligned with expected learning outcomes in biology education, particularly those related to higher-order thinking skills, and are systematically translated into measurable indicators and test items within the context of animal conservation issues.

Based on the aforementioned theoretical and conceptual considerations, this study aims to develop and establish the content validity of an instrument for assessing socioscientific problem-solving skills in the context of animal conservation. Specifically, this study seeks to answer the following research questions: (1) What are the characteristics of the developed instrument in measuring socioscientific problem-solving skills? and (2) How is the content validity of the instrument measured based on expert judgment? This study is expected to contribute to the advancement of assessment practices in biology education and support the implementation of more effective socioscientific issue-based learning

Methods

Research Design

This study employed a research and development (R&D) design aimed at developing and establishing the content validity of a Socioscientific Problem-Solving Skills (SSPS) instrument in the context of biology education. The development process followed a systematic instrument development framework, including construct identification, operational definition, item development, and expert validation (Nugroho et al., 2024). The procedure consisted of several stages: (1) identifying and defining the SSPS construct based on relevant literature; (2) developing a conceptual framework integrating socioscientific issue (SSI) components and problem-solving dimensions; (3) constructing an instrument blueprint; (4) developing test items based on animal conservation contexts; (5) conducting content validation through expert judgment; and (6) revising the instrument based on expert feedback (Budiyono, 2017). This study focused on the content validation stage as an essential step prior to further empirical validation. The research flow diagram can be seen in Figure 1.

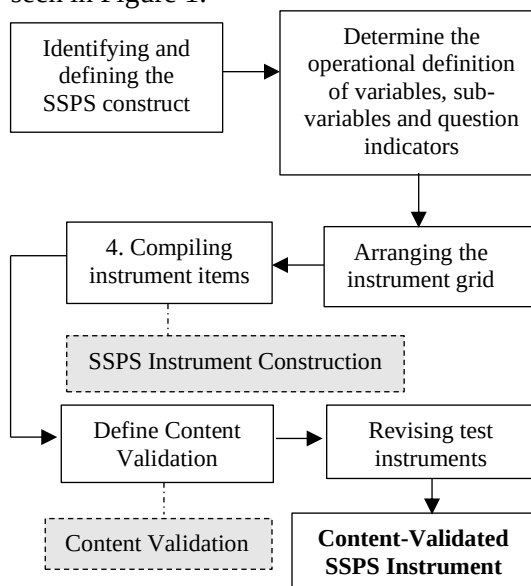


Figure 1. Research Procedures

Participants

The participants in this study were ten experts selected using purposive sampling. All participants were university lecturers in biology education with at least five years of experience in teaching and/or research in

science education. In addition, the experts had relevant expertise in educational assessment, instrument development, or experience as reviewers in academic publications. These criteria were established to ensure that the validation process was conducted by individuals with strong theoretical and methodological backgrounds in science education and assessment (Almanasreh et al., 2022; Sarkity et al., 2023).

Instrument Development

The instrument developed in this study was designed to assess students' socioscientific problem-solving skills within the context of animal conservation. The development of the instrument was grounded in a conceptual framework that integrates two main dimensions: (1) socioscientific issue (SSI) components and (2) problem-solving processes

The SSI components consisted of four elements: scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty. These components represent the essential dimensions involved in reasoning about complex socioscientific issues (Sadler, 2011; Zeidler et al., 2019). Meanwhile, the problem-solving dimension was operationalized into four sequential processes: defining the problem in an SSI context, exploring the problem through analysis of relevant information, planning solutions based on integrated considerations, and reflecting on and evaluating the proposed solutions (Nugroho et al., 2025; OECD, 2019).

Based on this framework, an instrument blueprint was developed to map the relationships among constructs, indicators, and test items. The instrument consisted of eight essay-based items designed to capture higher-order thinking skills. Each item was contextualized within real-world animal conservation issues to enhance ecological validity.

A validation sheet was also developed to assess each item based on five aspects: construct relevance, content appropriateness, item construction, scoring rubric, and language clarity. Each aspect was evaluated using a four-point Likert-type scale to indicate the degree of relevance (Marlina et

al., 2025; Nurjanah et al., 2023). The response categories were: 1 = not relevant, 2 = somewhat relevant, 3 = relevant, and 4 = highly relevant. A four-point scale was selected to avoid neutral responses and encourage experts to provide a clear judgment regarding the relevance of each assessment criterion.

Data Collection Procedure

Data were collected through an expert judgment process employing a modified Delphi method to establish the content validity of the developed instrument. The Delphi method was selected due to its strengths in facilitating iterative and anonymous consensus among experts, integrating multidisciplinary perspectives, and ensuring robust content validation. In addition, this method is particularly suitable for addressing the complexity of assessing higher-order skills, such as socioscientific problem-solving, which involve multiple dimensions including scientific reasoning, moral considerations, stakeholder perspectives, and uncertainty (Brady, 2015; Habibi et al., 2014).

The Delphi procedure in this study consisted of three main stages adapted from previous studies. In the first stage, a Focus Group Discussion (FGD) was conducted to review and evaluate the initial draft of the instrument. This stage involved a panel of ten experts in educational assessment and biology education, who provided initial feedback, suggestions, and critical input to improve the clarity, relevance, and structure of the instrument (Murgado-Armenteros et al., 2012; Tracey & Richey, 2007). The second stage involved iterative consultation with the expert panel to refine the instrument based on the feedback obtained during the FGD. Revisions were made to ensure alignment between the theoretical constructs and the operational indicators, as well as to improve the quality of items, scoring rubrics, and contextual relevance within animal conservation issues. The third stage focused on the formal evaluation of content validity. At this stage, the revised instrument was distributed to ten expert validators, who were selected based on their expertise in biology education assessment, experience in research and scientific publication related to

instrument development, and teaching experience in biology education. The experts were asked to evaluate each item using a validation questionnaire.

The validation instrument consisted of several key aspects, including construct alignment (SSPS and SSI components), content and contextual relevance, item construction, scoring rubric, and language clarity. Experts provided quantitative ratings using a Likert-type scale, as well as qualitative feedback in the form of comments and suggestions. The combination of iterative feedback and structured evaluation within the Delphi framework enhanced the credibility, rigor, and validity of the developed instrument (Hsu & Ohio, 2007; Sablatzky, 2022).

Data Analysis

Data analysis was conducted using both qualitative and quantitative approaches. Qualitative data derived from experts' comments and suggestions were analyzed descriptively and used as a basis for revising and refining the instrument.

Quantitative data were analyzed using Aiken's V coefficient to determine the degree of agreement among experts regarding the relevance of each item. Aiken's V was calculated based on the number of experts, the rating scale employed, and the scores assigned by each expert. The coefficient ranges from 0 to 1, where higher values indicate a higher level of agreement among experts (Lewis, 1985).

In this study, the minimum acceptable value of Aiken's V was set at 0.69, based on the number of experts ($n = 10$) and a significance level of 0.05 (Lewis, 1985). Items with Aiken's V values equal to or greater than 0.69 were considered to have acceptable content validity, while those below the threshold were subject to revision.

To facilitate a more nuanced interpretation of the results, the Aiken's V values were further classified into three categories: high (≥ 0.80), moderate (0.70–0.79), and relatively low (< 0.70). This classification was adapted from commonly used benchmarks in educational measurement literature (e.g., Cohen, 1988; Ilyana et al., 2025). However, it should be noted that Aiken's V does not have

universally established categorical thresholds. Therefore, this categorization was used as a supplementary interpretative framework rather than a strict criterion for determining item validity. Items with relatively lower values were carefully reviewed and refined, particularly in terms of item construction and scoring rubric clarity, rather than being immediately removed.

Result and Discussion

Development of the SSPS Conceptual Framework.

The development of the Socioscientific Problem-Solving Skills (SSPS) instrument began with a theoretical synthesis of the Socioscientific Issues (SSI) framework and the problem-solving framework. Rather than adopting these frameworks separately, this study integrated their complementary strengths to establish a conceptual foundation for assessing socioscientific problem-solving skills in authentic animal conservation contexts.

The SSI framework contributes four essential dimensions: scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty which characterize decision-making in complex socioscientific issues (Sadler, 2011; Zeidler et al., 2019). Meanwhile, the problem-solving framework provides a structured cognitive process consisting of problem identification, problem exploration, solution planning, and reflection and evaluation (OECD, 2019; Romine et al., 2016). Integrating these frameworks enables assessment of both cognitive and socio-ethical aspects of problem solving.

The theoretical synthesis embedded the SSI dimensions across each stage of the problem-solving process, resulting in four dimensions of SSPS: problem identification, problem exploration, solution planning, and reflection and evaluation (Table 1). These dimensions subsequently guided the development of assessment indicators, essay items, and analytic scoring rubrics presented in Table 1. The integration of SSI and problem-solving frameworks constitutes the conceptual novelty of this study and provides a coherent foundation for assessing socioscientific problem-solving skills in biology education.

Table 1. Theoretical Synthesis of SSI and Problem Solving Frameworks

SSI Dimension	Problem-Solving Framework	SSPS Dimension
Scientific Evidence	Define the Problem	Problem Identification
Scientific Evidence, Stakeholder Perspective	Explore the Problem	Problem Exploration
Moral Reasoning, Stakeholder Perspective	Plan Solutions	Solution Planning
Scientific Evidence, Moral Reasoning, Stakeholder Perspective, Uncertainty	Reflection and Evaluation	Reflection and Evaluation

Note: SSI components are mapped according to their primary relevance to each problem-solving stage. The mapping does not imply that each component is exclusively applicable to a single stage.

The problem-solving framework uses action-oriented terms to describe the stages of problem-solving, whereas SSPS dimensions use nouns to represent the competencies

being assessed. SSI components are mapped based on their primary relevance to each stage, rather than applied uniformly. Scientific evidence supports problem identification and exploration, while solution planning emphasizes moral reasoning and stakeholder perspectives. This mapping reflects their primary roles, although each component may also contribute to other stages. Overall, this synthesis provides a theoretical foundation for the SSPS assessment dimensions.

Development of the SSPS Assessment Instrument

Based on the synthesized SSPS framework, the next stage involved translating the conceptual framework into measurable assessment indicators and essay items. Each assessment indicator represents the integration of problem-solving processes with socioscientific dimensions and serves as the basis for developing the SSPS assessment instrument. Dimensions and Indicators of Socioscientific Problem-Solving Skills (SSPS) are presented in Table 2.

Table 2. Dimensions and Indicators of Socioscientific Problem-Solving Skills (SSPS)

Dimension	Indicator	Item Indicator	Item
Problem Identification	Mapping the interconnections among identified problems	Students are able to identify the interrelationships among land-use change, habitat fragmentation, changes in wildlife behavior, and socio-economic impacts on communities in the case of Sumatran tiger conflict.	1
	Determining the main problem to be addressed	Students are able to determine and provide scientific and social justification for the primary problem in the case of human–Sumatran elephant conflict.	2
Problem Exploration	Formulating problem statements based on the identified main problem	Students are able to formulate relevant scientific problem questions related to the decline of orangutan populations due to oil palm expansion.	3
	Identifying alternative solutions to address the problem	Students are able to identify and evaluate at least three alternative solutions to human–elephant conflict, including their ecological and social strengths and limitations.	4
Solution Planning	Designing a plan based on the selected solution	Students are able to describe the components of a wildlife corridor development program, including objectives, implementation stages, stakeholders involved, and success indicators.	5
	Implementing the planned solution	Students are able to explain concrete implementation steps of a conservation education program involving multiple community groups in a participatory manner.	6
Reflection and Evaluation	Identifying potential unintended consequences resulting from the implemented solution	Students are able to analyze indirect (secondary) impacts of conservation area designation policies on both social and ecological conditions.	7
	Reflecting on the strengths and weaknesses of the problem-solving process	Students are able to reflect on the strengths and weaknesses and provide scientifically and ethically grounded recommendations for improving wildlife relocation solutions.	8

Based on Table 2 show the first dimension, defining the problem, focuses on students' ability to identify and conceptualize complex socioscientific issues by analyzing the interconnections among ecological, social, and economic factors (Evagorou et al., 2017). For example, students are required to map relationships between habitat fragmentation, wildlife behavior, and socio-economic impacts in human-wildlife conflict cases. This indicates that the instrument does not merely assess problem recognition, but also emphasizes systemic thinking. The second dimension, exploring the problem, captures students' ability to formulate scientific questions and evaluate alternative solutions. At this stage, students are required to investigate the problem more deeply by integrating relevant scientific knowledge and contextual information. The inclusion of tasks such as identifying multiple solution alternatives and evaluating their strengths and limitations demonstrates that the instrument emphasizes analytical and comparative reasoning (Christenson et al., 2012; Yoon & Park, 2017).

The third dimension, solution planning, focuses on students' ability to design and implement solutions. This includes developing structured intervention plans, identifying stakeholders involved, and outlining implementation steps. The presence of these indicators reflects the instrument's orientation toward applied problem-solving

skills, where students are expected not only to think critically but also to propose feasible and contextually relevant solutions (Jafari & Meisert, 2023; Viehmann et al., 2024). The final dimension, reflection and evaluation, assesses students' ability to critically reflect on the outcomes of their solutions. This includes identifying unintended consequences and evaluating the strengths and weaknesses of proposed solutions. This dimension highlights the metacognitive aspect of problem solving, which is essential in addressing ill-structured socioscientific problems (Romine et al., 2016).

In addition to the problem-solving dimensions, the instrument is further characterized by the integration of four key SSI components: scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty. These components reflect the multidimensional nature of socioscientific reasoning, which requires individuals to evaluate evidence, consider ethical implications, acknowledge diverse perspectives, and deal with uncertainty in complex real-world issues (Ben-horin et al., 2023; Jimenez et al., 2024; Romine et al., 2016). Table 3 presents the mapping of socioscientific issue (SSI) components across the instrument items, showing how scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty are embedded within each problem context.

Table 3. Mapping of Socioscientific Issue (SSI) Components in the SSPS Instrument

SSPS Dimension	Item & Animal Conservation Context	Integrated SSI Components
Problem Identification	Item 1. Human–Sumatran tiger conflict due to habitat fragmentation	Scientific Evidence: Habitat fragmentation, wildlife behavior changes, ecosystem disruption caused by land-use change
	Item 2. Human–Sumatran elephant conflict in agricultural areas	Scientific Evidence: Elephant migration patterns, habitat loss, crop-raiding behavior
Problem Exploration	Item 3. Decline of orangutan populations due to oil palm expansion	Scientific Evidence: Deforestation, habitat loss, biodiversity impacts. Stakeholder Perspective: Plantation companies, NGOs, government, local communities.
	Item 4. Alternative solutions to human–elephant conflict	Scientific Evidence: Habitat restoration, wildlife corridors, deterrent technologies. Stakeholder Perspective: Communities, conservation agencies, policymakers, researchers.
Solution Planning	Item 5. Wildlife corridor development program	Moral Reasoning: Responsibility for biodiversity conservation. Stakeholder Perspective: Government, conservation organizations, communities, landowners.
	Item 6. Community-based conservation education program	Moral Reasoning: Responsibility for promoting sustainable practices. Stakeholder Perspective: Community groups, educators, NGOs, policymakers.
	Item 7. Conservation area designation policy	Scientific Evidence: Ecosystem protection and biodiversity conservation. Moral Reasoning: Conservation versus

SSPS Dimension	Item & Animal Conservation Context	Integrated SSI Components
Reflection and Evaluation		community livelihoods.Stakeholder Perspective: Government, indigenous/local communities, conservation groups.Uncertainty: Social and ecological consequences of policy implementation.
	Item 8. Wildlife relocation solutions	Scientific Evidence: Species adaptation and habitat suitability.Moral Reasoning: Animal welfare and human intervention.Stakeholder Perspective: Conservationists, local communities, government, researchers.Uncertainty: Relocation success and ecological risks.

Based on Table 3 show these components are embedded across all items to ensure that the instrument captures the complexity of socioscientific reasoning. The scientific evidence component requires students to utilize relevant ecological and biological knowledge, such as habitat loss, species behavior, and ecosystem dynamics, in analyzing problems. The moral reasoning component challenges students to consider ethical dilemmas, such as balancing conservation efforts with human needs. The stakeholder perspective component encourages students to evaluate problems from multiple viewpoints, including those of local communities, governments, and conservation organizations. Meanwhile, the uncertainty component addresses the inherent unpredictability of socioscientific issues, requiring students to acknowledge limitations in data and the potential variability of outcomes (Ben-horin et al., 2023; Jafari & Meisert, 2023; Jimenez et al., 2024).

Importantly, the integration of these SSI components across different problem-solving stages demonstrates that the instrument does not treat socioscientific reasoning as a separate construct, but rather as an integral part of the problem-solving process. This integrated design enables the instrument to capture the multidimensional and dynamic nature of socioscientific problem-solving skills (Ben-horin et al., 2023; Romine et al., 2016). Furthermore, the contextualization of all items within animal conservation issues enhances the ecological validity of the instrument. The use of authentic cases, such as human wildlife conflict, deforestation impacts, and conservation policies, ensures that students engage with realistic and meaningful problems (Pooley et al., 2020; Viehmann et al., 2024). This contextual approach is critical in assessing higher-order thinking skills, as it

situates cognitive processes within real-world scenarios (Yacoubian & Khishfe, 2018).

The findings of this study (Table 1,2) demonstrate that the developed instrument possesses strong conceptual characteristics, particularly in its ability to integrate problem-solving processes with socioscientific reasoning components. This integration addresses a key limitation in prior assessment approaches, which often measure constructs such as argumentation or decision-making in isolation rather than as interconnected processes.

The multidimensional structure of the instrument reflects the theoretical perspective that socioscientific problem solving involves both cognitive and socio-ethical dimensions. By incorporating scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty into each stage of problem solving, the instrument captures the interplay between knowledge, values, and contextual considerations. This confirms that the instrument is conceptually grounded in contemporary socioscientific reasoning frameworks. Recent studies have emphasized that effective engagement with socioscientific issues requires the integration of evidence evaluation, ethical reasoning, perspective-taking, and contextual decision-making processes (Ben-horin et al., 2023; Romine et al., 2016). Furthermore, socioscientific reasoning is increasingly viewed as a dynamic and interconnected process rather than a collection of isolated cognitive skills (Jimenez et al., 2024). The present study extends these perspectives by embedding SSI components into a structured problem-solving framework, thereby offering a more operational, measurable, and contextually grounded approach to assessing socioscientific problem-solving skills (Kusumadani et al., 2026; Viehmann et al., 2024; Yacoubian & Khishfe, 2018).

Another important strength lies in its focus on ill-structured problem solving. The inclusion of uncertainty and multiple stakeholder perspectives ensures that the tasks do not lead to a single correct answer, but instead require students to engage in complex and reflective reasoning (Leung et al., 2025; Tidemand & Nielsen, 2017). The explicit inclusion of reflection and evaluation further extends the assessment beyond solution generation, emphasizing metacognitive processes that are often underrepresented in similar instruments (Bächtold & Pallarès, 2022). In addition, the use of animal conservation as the contextual basis enhances the ecological validity of the instrument. Such contexts inherently involve scientific complexity, ethical dilemmas, and competing stakeholder interests, making them highly suitable for assessing socioscientific problem-solving skills (Grace & Grace, 2009; Kinslow et al., 2018).

The use of animal conservation as the central context further strengthens the domain-specific relevance of the instrument, particularly in biology education. Issues such as human wildlife conflict, habitat fragmentation, and biodiversity loss require students to integrate ecological concepts with ethical and socio-political considerations. This makes conservation contexts especially appropriate for operationalizing socioscientific problem-solving, as they naturally involve trade-offs between environmental sustainability and human interests (Friedrichsen et al., 2020; Kansky et al., 2016). Recent studies have also shown that environmental and conservation issues can promote students' higher-order thinking, critical reasoning, and ethical awareness in science learning contexts (Zo'bi, 2014). Furthermore, conservation-based learning contexts provide authentic educational experiences that reflect the complexity of real-world socio-ecological systems (Navarro-perez & Tidball, 2012).

Importantly, the instrument is specifically designed for pre-service biology teachers, who are expected not only to master biological concepts but also to facilitate students' reasoning on complex socioscientific issues. Therefore, the ability to analyze conservation problems, evaluate

evidence, and consider multiple stakeholder perspectives represents a critical competency for future biology educators (Ceyhan et al., 2021). In this regard, the instrument does not merely assess problem-solving skills but also supports the development of pedagogically relevant reasoning abilities, particularly in facilitating discussion and decision-making related to socioscientific issues (Nida et al., 2020). Recent studies have also emphasized that teacher education should promote reflective and multidimensional reasoning skills to prepare future educators for addressing complex real-world scientific problems (Dejanovikj & Höttecke, 2024; Karışan & Eilks, 2023). Taken together, these findings address the first research question by demonstrating that the developed instrument is conceptually coherent, multidimensional, and aligned with the nature of real-world socioscientific problems.

Content Validity of the SSPS Instrument

The second research question aims to examine the extent to which the developed instrument meets the criteria of content validity based on expert judgment. The results of the Aiken's V analysis indicate that all items of the SSPS instrument meet the minimum validity threshold, demonstrating a high level of agreement among experts regarding the relevance and appropriateness of the instrument (Nurjanah et al., 2023; Ulfah et al., 2020). Overall, the Aiken's V values for all items across all assessment aspects ranged from 0.67 to 1.00. The majority of the values were above 0.80, indicating a high level of expert agreement. Based on the predetermined threshold ($V \geq 0.69$), all items were categorized as valid, suggesting that the instrument has acceptable content validity and is suitable for further empirical testing (Badenes-ribera et al., 2020).

To provide a more comprehensive evaluation, the Aiken's V values were analyzed across five assessment aspects: construct alignment, content and context, item construction, scoring rubric, and language clarity. The results of the average Aiken's V values for each aspect are presented in Table 4.

Table 4. Aiken’s V Coefficients for Each Item Across Validation Aspects

Validation Aspect	Item								Mean
	1	2	3	4	5	6	7	8	
Construct Alignment (SSPS & SSI)	0.84	0.81	0.78	0.90	0.82	0.86	0.81	0.83	0.82
Content and Context	valid	valid	valid	valid	valid	valid	valid	valid	valid
	0.88	0.80	0.80	0.86	0.85	0.79	0.85	0.83	0.85
Item Construction	valid	valid	valid	valid	valid	valid	valid	valid	valid
	0.92	0.91	0.92	0.88	0.96	0.90	0.93	0.89	0.88
Scoring Rubric	valid	valid	valid	valid	valid	valid	valid	valid	valid
	0.89	0.88	0.90	0.92	0.96	0.88	0.89	0.88	0.88
Language	valid	valid	valid	valid	valid	valid	valid	valid	valid
	0.90	0.94	0.94	0.96	1.00	0.94	0.93	0.92	0.90
	valid	valid	valid	valid	valid	valid	valid	valid	valid

The findings (Table 4) show that the language aspect obtained the highest average value ($V = 0.90$), followed by item construction and scoring rubric ($V = 0.88$), content and context ($V = 0.85$), and construct alignment ($V = 0.82$). These results indicate that all aspects fall validity categories, reflecting strong agreement among experts in evaluating the overall quality of the instrument.

The consistently high Aiken's V values indicate that the SSPS framework was successfully translated into measurable assessment items. The relatively lower values in the construct alignment aspect suggest that integrating multiple SSI dimensions within a single task is inherently complex. This finding highlights the importance of iterative expert validation to ensure that the theoretical constructs are accurately represented in the assessment items. In addition, the results also reflect a strong level of agreement among experts regarding the relevance, clarity, and appropriateness of the instrument (Almanasreh et al., 2022).

Among the evaluated aspects, language, item construction, and scoring rubric demonstrate particularly strong performance, suggesting that the items are clearly formulated, structurally sound, and supported by well-defined assessment criteria. This is essential in ensuring that the instrument accurately captures students' cognitive processes without being confounded by ambiguity or misinterpretation (Worthington et al., 2024).

The high level of expert agreement aligns with previous studies in educational measurement that utilize Aiken’s V to establish content validity, where high coefficients indicate strong relevance and representativeness of the construct (Kania et al., 2024; Nurjanah et al., 2023).

The construct alignment aspect also demonstrated a high level of validity, confirming that the integration of socioscientific issue components—scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty—with problem-solving dimensions was successfully operationalized within the instrument. This finding supports previous studies emphasizing that strong alignment between theoretical constructs and instrument indicators provides important evidence of content and construct validity (Guo et al., 2024; Smith et al., 2020). Furthermore, high expert agreement obtained through Aiken’s V analysis indicates that the instrument items are representative of the intended construct and suitable for subsequent empirical validation (Nurjanah et al., 2023; Pratiwi & Yamtinah, 2025).

Item-Level Validity and Classification

To provide a more nuanced interpretation of the content validity results, the Aiken’s V values were classified into three categories: high, moderate, and relatively low. The classification results are presented in Table 5.

Table 5. Classification of Aiken’s V Values Across Items and Validation Aspects

Validation Aspect	Item							
	1	2	3	4	5	6	7	8
Construct Alignment (SSPS & SSI)	High	High	Moderate	High	High	High	High	High
Content and Context	High	Moderate	Moderate	High	High	Moderate	High	High

Validation Aspect	Item							
	1	2	3	4	5	6	7	8
Item Construction	High	High	High	High	High	High	High	High
Scoring Rubric	High	High	High	High	High	High	Moderate	High
Language	High	High	High	High	High	High	High	High

As shown in Table 5, the majority of items across all validation aspects fall within the high category, indicating strong agreement among experts regarding the relevance and appropriateness of the instrument items. The item construction and language aspects demonstrate the highest consistency, with all items classified as high. This suggests that the tasks are systematically structured, academically appropriate, and capable of eliciting higher-order thinking while remaining clear and accessible to students (OECD, 2019; Susantini et al., 2025). In addition, the high classification in the language aspect indicates that the items are free from ambiguity, allowing students to focus on reasoning processes rather than interpreting the meaning of the questions (Bhakti et al., 2025).

In contrast, a small number of items fall within the moderate category, particularly in the content-context and construct alignment aspects. This indicates that although the items generally meet validity requirements, several indicators may still require minor refinement to strengthen their alignment with the intended construct and socioscientific context representation (Polit et al., 2007; Taherdoost, 2016). Nevertheless, only a very limited number of indicators approach the lower boundary of validity, and no items fall into a critically low category requiring elimination. Overall, the classification results confirm that all items satisfy the minimum validity threshold and are suitable for further implementation and empirical validation (Kania et al., 2024; Kusumadewi et al., 2025).

However, a small number of items fell within the moderate category, particularly in the content-context and construct alignment aspects. This variation reflects the inherent complexity of integrating multiple socioscientific components within a single task. Previous studies on socioscientific and complex problem-solving assessments have similarly reported variability in expert judgment due to the multidimensional and ill-structured nature of the constructs being

measured (Graesser et al., 2017; Lee & Grace, 2012). Moreover, animal conservation issues are widely recognized as complex socioscientific problems characterized by ecological uncertainty, dynamic systems, ethical dilemmas, and competing stakeholder interests (Agustian, 2025; Rohmah et al., 2022). Therefore, differences in expert evaluations are more appropriately interpreted as reflections of the challenges associated with representing authentic socioscientific contexts rather than as weaknesses of the instrument itself.

In addition, moderate classifications in the scoring rubric aspect suggest that clearer differentiation among performance levels may further enhance evaluation consistency. This challenge is commonly reported in assessments involving open-ended and complex responses, where subjective judgment and rater effects may influence scoring accuracy and reliability (Han & Lu, 2021; Palermo, 2022). Previous studies have emphasized that well-defined rubric descriptors and continuous rubric refinement are essential for improving inter-rater consistency and reducing ambiguity in performance assessment (Khodi, 2021; Wahyuni et al., 2021). Overall, the classification results indicate that the instrument demonstrates strong item-level validity, with only minor refinements required to optimize clarity and scoring consistency.

Instrument Refinement Based on Expert Feedback

Qualitative data in the form of expert feedback were also systematically analyzed alongside the quantitative Aiken's V analysis to further refine the SSPS instrument. The results indicate that although all items met the minimum content validity criteria, several aspects required minor revisions to enhance clarity, construct alignment, and the integration of socioscientific issue (SSI) components (Boateng et al., 2018; Zamanzadeh et al., 2015). The detailed suggestions provided by experts and the

corresponding revisions made to the instrument are presented in Table 6.

Table 6. Expert Feedback and Corresponding Revisions

No	Expert Feedback	Follow-up (Revisions)
1	In Item 1, the cause effect relationship is clearly presented; however, the item does not explicitly prompt students to use scientific evidence in their responses.	The item was revised by adding prompts that explicitly require the use of ecological concepts or data as a basis for analysis (scientific evidence).
2	In Item 2, the identification of the main problem is appropriate; however, the social and ethical considerations are not sufficiently emphasized.	The wording of the item was refined to encourage students to consider social impacts and ethical aspects (moral reasoning).
3	In Item 3, the scientific questions are relevant; however, they do not fully encourage students to consider uncertainty.	Additional phrases were incorporated to prompt students to address potential long-term impacts and limitations of predictions (uncertainty).
4	In Item 4, the proposed solutions are varied; however, they do not fully reflect the involvement of multiple stakeholders.	The item was revised to explicitly encourage consideration of various stakeholder perspectives (e.g., community, government, and conservation agencies).
5	In Item 5, the solution plan is systematic; however, the success indicators are not explicitly addressed.	The item and rubric were refined to emphasize the inclusion of measurable success indicators in the proposed solutions.
6	In Item 6, the implementation steps are clear; however, potential constraints or challenges are not sufficiently explored.	The item was revised to prompt students to identify potential barriers and propose strategies to address them.
7	In Item 7, the impacts of policy are identified; however, the range of ecological and social impacts could be further elaborated.	The context of the item was expanded to encourage analysis of both ecological and social impacts.
8	In Item 8, the reflection on solutions is appropriate; however, it does not sufficiently emphasize evidence-based evaluation.	The item was revised to encourage students to provide reflections supported by scientific evidence (evidence-based evaluation).
9	In the scoring rubric (particularly between levels 3 and 4), the distinctions are generally clear but could be further refined.	The rubric descriptors were revised to ensure clearer and more operational distinctions between performance levels.
10	In several items (Items 1, 3, and 6), the sentence structure is relatively complex and may increase students' cognitive load.	The wording of these items was simplified while maintaining their scientific meaning to improve clarity and readability.

Based on Table 6, expert feedback focused on three main areas: (1) strengthening the integration of SSI components, (2) improving the clarity and specificity of item construction, and (3) refining the scoring rubric. Several items required enhancement to explicitly incorporate key SSI components, such as scientific evidence, moral reasoning, stakeholder perspectives, and uncertainty.

For instance, Item 1 was revised to more explicitly require the use of scientific evidence in analyzing causal relationships, while Item 2 was improved to better elicit moral and social considerations. Similarly, Item 3 was refined to incorporate elements of uncertainty, and Item 4 was adjusted to emphasize stakeholder involvement in evaluating alternative solutions. These revisions demonstrate that the initial version of the instrument, although valid, still

required strengthening in capturing the multidimensional nature of socioscientific reasoning.

Revisions were also made to improve the operational clarity of problem-solving tasks. For example, Item 5 was enhanced by explicitly requiring the formulation of success indicators, while Item 6 was revised to include the identification of potential constraints and mitigation strategies. In Item 7, the scope of analysis was expanded to include both ecological and social impacts, and Item 8 was refined to emphasize evidence-based reflection.

In addition, experts highlighted the need to improve the scoring rubric, particularly in differentiating performance levels. As a result, rubric descriptors especially for intermediate and high performance levels were revised to ensure clearer and more consistent assessment

criteria. Linguistic refinement was also conducted, including simplifying sentence structures in several items (e.g., Items 1, 3, and 6) to reduce cognitive load without compromising scientific meaning.

The qualitative feedback obtained from experts provides important complementary evidence to the quantitative validity results and plays a crucial role in refining the instrument. Previous studies have similarly emphasized that iterative refinement through expert consultation is essential in Delphi-based instrument development, as it supports systematic improvement, consensus-building, and enhancement of measurement quality (Jandhyala, 2020; Mokkink et al., 2020).

Several items were revised to more explicitly incorporate core socioscientific issue (SSI) components. For example, the inclusion of scientific evidence was strengthened in analytical tasks, moral reasoning was emphasized in decision-making contexts, and uncertainty was more clearly embedded in problem exploration. These revisions ensure that each item more comprehensively represents the multidimensional nature of socioscientific problem solving, which involves evidence evaluation, ethical reasoning, perspective taking, and contextual complexity (Sparks et al., 2022; Zeidler et al., 2019). In addition, several refinements emphasized the representation of ecological complexity within animal conservation contexts, including long-term environmental impacts, stakeholder involvement, and policy-related considerations. Previous studies have similarly highlighted that authentic conservation-based SSI learning requires engagement with complex sustainability challenges characterized by uncertainty, competing interests, and interconnected ecological systems (Agustian, 2025; Jackson et al., 2023).

Improvements were also made to enhance the operational clarity of tasks. This included refining prompts to require clearer identification of success indicators, consideration of implementation constraints, and analysis of broader ecological and social impacts. Such revisions contribute to more precise measurement of students' problem-solving processes by ensuring stronger

alignment between task demands and targeted reasoning skills (Ehrich et al., 2021; Vo & Simmie, 2025). In addition, the scoring rubric was revised to improve differentiation between performance levels, thereby enhancing the reliability and interpretability of assessment results. Linguistic refinements were also conducted to simplify sentence structures and reduce unnecessary cognitive load, ensuring that item complexity reflected intended cognitive demand rather than linguistic difficulty (Noroozi & Karami, 2022; Vattanavanit et al., 2022).

These revisions demonstrate that content validation is not merely a statistical procedure but also a process of conceptual refinement. Most expert comments focused on improving construct alignment and contextual representation rather than correcting scientific inaccuracies, indicating that the conceptual foundation of the SSPS framework was already robust. The revision process therefore played an important role in strengthening the correspondence between the theoretical framework and its operationalization into authentic assessment tasks.

Integrated Validity Argument and Implications

The integration of quantitative and qualitative findings strengthens the overall validity argument of the instrument. While the Aiken's V analysis confirms a high level of expert agreement, the qualitative feedback ensures that the instrument is also conceptually robust and practically applicable. This integration of multiple sources of evidence is consistent with contemporary validation frameworks, which emphasize that validity should be supported through both quantitative and qualitative approaches (Folger & Bostic, 2023; Sireci & Benítez, 2023). Furthermore, iterative validation supported by the Delphi method contributes to systematic refinement, consensus-building, and enhanced methodological rigor in instrument development (Oxley et al., 2025; Parejo, 2022; Veugelers et al., 2020). The combination of strong conceptual grounding, high content validity, and continuous refinement indicates that the instrument is well-positioned for subsequent validation

stages, including construct validity and reliability testing (Setiawan et al., 2024).

From a pedagogical perspective, the instrument holds particular relevance for biology teacher education. Previous studies have emphasized the importance of preparing pre-service biology teachers to facilitate socioscientific reasoning, environmental decision-making, and evidence-based argumentation in science classrooms (Faisal et al., 2025; Ladachart & Ladachart, 2022). Furthermore, integrating socioscientific problem-solving within conservation contexts supports broader educational goals related to sustainability, environmental literacy, and systems thinking (Bernhardt & Wilde, 2026; Schmäing et al., 2026). Such approaches are also recognized as contributing to transformative learning by fostering ecological awareness, sustainability competencies, and environmental responsibility among future teachers (Nasir et al., 2026; Rasis et al., 2023).

From a broader perspective, the developed SSPS instrument contributes to the advancement of socioscientific assessment by providing a comprehensive framework that integrates cognitive, ethical, and contextual dimensions. Previous studies have emphasized that socioscientific learning and assessment should incorporate evidence evaluation, moral reasoning, perspective taking, and contextualized problem solving to adequately represent the complexity of real-world issues (Viehmann et al., 2024; Zeidler et al., 2019). This contribution addresses a critical limitation in conventional assessment practices, which often fail to capture the multidimensional nature of socioscientific reasoning and environmental decision-making (Arroyavea et al., 2021). Furthermore, SSI-based educational approaches have been shown to support environmental literacy, interdisciplinary thinking, character development, and transformative learning in biology education contexts (Atabey & Topçu, 2025; Leij et al., 2024; Rifa'i & Subiantoro, 2022).

Overall, the findings demonstrate that the instrument is not only valid but also theoretically and practically meaningful for both research and biology. The present findings also provide a foundation for future research on authentic assessment in biology

education. The conceptual integration of socioscientific issue dimensions with structured problem-solving processes offers a framework that may be adapted to other socioscientific contexts, such as biodiversity conservation, climate change, biotechnology, and environmental sustainability. Nevertheless, further empirical validation involving larger student samples is required to establish the construct validity, reliability, and broader applicability of the developed instrument.

Conclusion

This study successfully developed and established the content validity of a Socioscientific Problem-Solving Skills (SSPS) instrument for biology education in the context of animal conservation. The instrument is grounded in a theoretical synthesis of the Socioscientific Issues (SSI) and problem-solving frameworks, resulting in four SSPS dimensions: problem identification, problem exploration, solution planning, and reflection and evaluation. Content validation using a modified Delphi method demonstrated that all assessment items met acceptable validity criteria, indicating that the instrument is suitable for assessing socioscientific problem-solving skills in biology education.

Theoretically, this study contributes a conceptual framework that integrates SSI dimensions with structured problem-solving processes, providing a foundation for future assessment development in socioscientific learning. Practically, the instrument offers biology educators and researchers a validated tool for assessing students' socioscientific problem-solving skills in authentic conservation contexts. However, the findings are limited to expert based content validation and should not be interpreted as evidence of the instrument's psychometric performance. Further studies are needed to examine construct validity, reliability, and applicability across broader educational contexts. Future research should examine the instrument's construct validity and reliability through empirical testing with pre-service biology teachers. The instrument may also be implemented in biology teacher education to assess socioscientific problem-solving skills and support instructional improvement.

Statement on the Use of AI in the Writing Process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing, sentence refinement, and improving responses to reviewers' comments. After using this tool, the authors carefully reviewed, verified, and revised the manuscript as necessary and take full responsibility for the final content of the article.

Conflict of Interest Statement

The authors declare that they have no competing financial or non-financial interests that could have influenced the study design, instrument development process, data analysis, interpretation of the findings, or publication of this manuscript.

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