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Exploring Indigenous Science to Identify Contents and Contexts for Science Learning in Order to Promote Education for Sustainable Development

Robby Zidny ^{1,2} , S Solfarina ², Ratna Sari Siti Aisyah ² and Ingo Eilks ^{1,*} 

¹ Department of Biology and Chemistry, Institute for Science Education (IDN)-Chemistry Education, University of Bremen, 28334 Bremen, Germany; robbyzidny@untirta.ac.id

² Department of Chemistry Education, Faculty of Teacher Training and Education, University of Sultan Ageng Tirtayasa, Serang 42117, Indonesia; solfarina@untirta.ac.id (S.S.); ratnasari@untirta.ac.id (R.S.S.A.)

* Correspondence: ingo.eilks@uni-bremen.de

Abstract: Indigenous science is comprised of the science-related knowledge and associated practices of indigenous cultures. Indigenous science provides rich contexts that can contribute to understanding the relationship of sociocultural life and environmental ethics in certain communities. It can also lead to better reflection upon Western modern views of science. Based on a qualitative analysis of indigenous science in the Baduy community (Indonesia), we describe how indigenous science can provide relevant contexts for students to learn scientific concepts, as well as help them to recognise the value of promoting sustainability. We present potential topics encompassing the sociocultural context of Baduy science that can be associated with sustainability issues. Topics were identified from six themes (agriculture, medicine, natural dyes, household chemicals, renewable energy, and astronomy). Potential implications of these topics to science learning are also presented. We view contextualization of science teaching and learning by indigenous science as a promising source to enhance students' perception of the relevance of science learning. It can also promote education for sustainable development.

Keywords: context-based learning; socioscientific issues; indigenous science; sustainability; education for sustainable development



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1. Introduction

Context-based learning (CBL) has been widely applied in science education since the 1990s [1]. Many researchers suggest that CBL helps to improve meaningful science education. Problems that CBL is intended to respond to are viewed as stemming from various factors. These include too much focus on the decontextualized learning of facts and theories, a lack of skills developed to apply knowledge in new situations, perceived confusion among students about the actual purpose of learning science, and students' perception of the science curriculum as irrelevant and incoherent [2]. CBL research has led to the implementation of programmes in several countries, including Salters in the UK, ChemCom in the USA, or Chemie im Kontext in Germany. All of these programmes have contributed to the understanding of meaningful science learning and start from real-world contexts [1]. However, specific contexts for science learning in one country may not be relevant in another land that has a different culture and traditions. Moreover, many contexts used in common CBL science curricula are mostly restricted to a Western modern view of the history and application of science. This view often neglects other cultural components (e.g., [3,4]).

There are some proposed ideas for raising the perception of the relevance of science learning. Some researchers have suggested that meaningful contexts must concern themselves with various natural and environmental phenomena. This includes any applications

of science in a given cultural and socioeconomic environment. In the different regions of the world, there are various environments. Each has unique and diverse cultural influences, for example, with respect to indigenous communities. In such communities, the path of knowing about nature has been orally passed down from ancestors and forms various types of indigenous science (ISc). This knowledge may provide relevant contexts for science learning, which are potentially interesting to students living in or near a corresponding environment. Beyond the contextualization of science, indigenous perspectives might contribute to understanding the relationship between sociocultural and environmental ethics. They might also help to better understand the dominant Western modern view of science through the lens of more holistic perspectives [5]. Doing so might aid researchers to form a more balanced view of education for sustainability, as has already been suggested by Sjöström et al. [6].

The idea of using ISc to identify contexts for science education is not new [7–10]. Some researchers see science teaching connected to ISc as an aid to promote the values of nature conservation in the sense of sustainability. This can contribute to developing critical reflection on the interrelationship between science and culture. However, we must maintain caution in order to foster an understanding of ISc in science education. The focus of teaching should neither be restricted to teaching the content knowledge behind ISc and its applications nor to solely promoting the idea of conserving the natural environment. The context should include a view of societal issues that involves students in discussions about sustainability in all its dimensions (sociocultural, economic, and environmental) [11]. In this way, education can enable students to play a role as responsible citizens and provide them with a chance to make positive changes in their lives [12].

If we wish to integrate ISc into science education, pedagogical approaches have been suggested that incorporate the sociocultural context, local wisdom, and various philosophical aspects of indigenous lifestyles into the sense of sociocritical sustainability issues [5]. In our view, one potential pedagogical approach to science learning is the philosophy behind education for sustainable development (ESD). This approach combines a wider perspective on sustainability, connected with science education based on socioscientific issues (SSIs) [11]. ESD in connection with SSI-based science education is believed to contribute to all three domains of relevant science teaching (personal, societal, and vocational relevance) as suggested by Stuckey et al. [13]. It is relevant for individual action. Examples of this include cases involving the consumption of resources, participation in societal debates on issues of sustainable development, and career choices related to sustainable science and technology [14,15]. The sociocultural aspects of ISc can be incorporated into ESD and can serve as potential contexts for realizing relevant science learning. Such contexts can encourage teachers and students to gain respect for local cultures, as well as provide ways to teach and learn locally relevant knowledge and skills. This in turn can improve the relevance of science learning. It also promotes ESD by extracting value from the local wisdom of indigenous people and joining it with Western modern views of science [16].

An ISc case study of the Baduy tribe in Indonesia revealed that indigenous communities generally apply scientific principles and concepts in sustainable ways. We can understand these aspects as ethnochemistry, ethnobotany, ethnomathematics, and ethnoastronomy [17]. The current paper uses the ESD framework [11], socioconstructivist pedagogy [18], and the suggested five criteria for selecting socioscientific issues for science education [19] to reach its conclusions. The study discusses the incorporation of Baduy science-related indigenous knowledge (IK) into context-based, sustainability-oriented science education. Exploration of the Baduy community's ISc is presented as a case study, which shows how to extract potential ISc topics that are related to sustainability issues. In this study, we analyse the relationship between ISc applied in the Baduy community within the science content of the Indonesian science curricula. The analysis identified related science content associated with the different educational levels in Indonesia. Using the concept of ESD, the study suggests different sustainability aspects that can be integrated in

science classrooms in Indonesia and in other countries. Then, it looks at the inferences that can be drawn from the study to aid in science education.

2. Theoretical Framework

2.1. Science in a Multicultural Perspective and ISc

Science is described as a collection of knowledge and methods that shape our perception of the natural world [20]. The theory of multicultural science education recognizes science as a cultural enterprise [21]. Thus, knowledge will be perceived differently according to the cultural traditions and the perspectives of the community who adhere to them. Ogawa defined the multisience perspective as encompassing three categories: personal science (referring to science at the individual level); ISc (referring to science at the cultural or societal level); and Western, modern science (referring to a collective rational perceiving nature and technology shared and authorized by the scientific community) [22].

Within a multisience perspective, ISc encompasses the science-related knowledge and practices of specific indigenous cultures [5]. It shapes the body of knowledge about nature and the interactions with nature practiced by indigenous peoples. These aspects are inherited by each culture and provide insights into indigenous societies [20]. ISc has also been interpreted by other academics under different names such as traditional (native) knowledge [23], ethnoscience [24], and traditional ecological knowledge (TEK) [5].

2.2. ISc as a Sociocultural Context for Science Learning to Promote ESD

Gilbert described “context” as a situation that gives meaning to words, phrases, and sentences [2]. He pointed out that well-suited contexts in science learning are very important. They have the potential to provide coherent meanings to science concepts, since they connect meanings to situations set within a broader point of view. Context in science education plays the role of a bridge that connects abstract concepts to everyday life experiences. Many researchers believe that this strengthens learners’ perception of the relevance and meaningfulness of science learning among students.

Contexts selected for science education should be essential to the life of the students in any given society. Science learning that starts with a context is viewed as relevant education if it is connected to authentic sustainability issues [14]. One contextual approach suggested for promoting ESD focuses specifically on ISc [16]. The acknowledgement of ISc has already been discussed also on a global educational policy level in order to promote sustainable development, which makes it relevant for ESD. The United Nations Educational, Scientific and Cultural Organization (UNESCO) initiated the Local and Indigenous Knowledge System (LINKS) [25]. This programme explores the ways that indigenous and local knowledge systems can contribute to understanding, mitigating, and adapting to climate change, environmental degradation, and biodiversity loss. Recent research trends in science education [7–10] use the sociocultural context of ISc to promote environmental education and ESD. They do so by focusing on socioecological issues such as biodiversity loss.

2.3. ESD in Science Education and Related Pedagogical Approaches

Sustainable development is commonly depicted by numerous models. The most widely accepted ones encompass ecological, economic, and sociocultural sustainability. These aspects are interconnected through various pathways [26]. The corresponding educational paradigm, which is related to sustainable development, is called ESD [11]. Based on a literature review, Burmeister et al. identified four basic strategies of ESD pedagogy when it comes to science education [11]. They include green laboratory practices, contextualizing science learning by sustainability questions, using sustainability questions for socioscientific issue-based science education, and operating sustainable development as part of the development of educational institutions. As Burmeister et al. [11] and Juntunen and Aksela [18] have already pointed out, SSI-based education is among the most promising strategies for achieving ESD in science education. SSIs encourage learners to participate in ethical, political, and environmental realms, which are related to science, technology,

society, and the environment in everyday life [27]. The applications of socioscientific issues in science education are believed to be controversial, up-to-date, complex, and relevant to the daily lives of students [28]. Simonneaux and Simonneaux even pointed out that sustainable development itself can be considered as a complex and highly relevant socioscientific issue [29].

Juntunen and Aksela [18] and Sjöström et al. [6] have suggested socioconstructivist and critical pedagogical approaches when carrying out ESD in science education. Some elements of the pedagogical approach presented by Juntunen and Aksela [18] should be involved when teaching ESD in science, for example, inquiry, interdisciplinary, and argumentation (Figure 1).

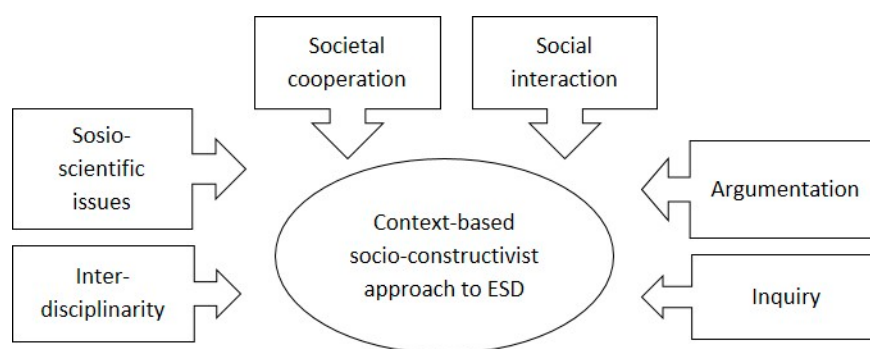


Figure 1. Elements of a context-based socio-constructivist education for sustainable development (ESD) pedagogy (adapted from Juntunen and Aksela [18]).

Science learning with ESD should teach science in context- or SSI-based educational environments. These activities encourage students to act based on their own ideas and experiences. Accordingly, the context of science learning should be provided by SSIs. In other words, they should be sociocritical, problem-oriented issues. Marks and Eilks [19], later supplemented by Stolz et al. [30], suggested five criteria for selecting issues to deliver the context for sociocritical and problem-oriented settings:

- **Authenticity:** the topic is authentic when it is up-to-date and currently being discussed within society and public media.
- **Relevance:** the topic is relevant if respective decisions are to come that will affect the current or future lives of students or other citizens within society
- **Evaluation is undetermined in socio-scientific respect:** the public perception of the issue includes different points of view that are part of the public debate.
- **Allows for open discussion:** the topic can openly be discussed in a public debate without harming individuals or groups in society.
- **Deals with questions from science and technology:** this topic concerns itself with a techno-scientific query.

Within these different theoretical frameworks, the ISc of the Baduy community in western Java (Indonesia) is explored and reflected upon to see whether it can provide any useful contexts for science education. The study is an educational analysis of the results of previous ethnographic research [17] in the inventory of Baduy ISc.

3. Materials and Methods

This study is a part of a larger educational design framework to incorporate indigenous ISc into science education [16]. In a previous study [17], ethnographic research was conducted on the Baduy community with the help of observation, interviews, documentation, and FGD (focus group discussion) to explore their ISc-related knowledge. Further analysis is given in this paper to expand upon the relationship between ISc applied in the Baduy community within the content of the Indonesian science curriculum. The analysis was carried out using the basic tenets of qualitative content analysis according to

Mayring [31]. To ensure validity of the data, triangulation was utilized. It compared data obtained in previous field studies with other pre-existing literature related to ISc of the Baduy community (see [32,33]). The data were analysed in two stages:

Stage 1—Thematic analysis focusing on example topics that could be used as contexts for science learning: The thematic analysis involved six phases: familiarizing ourselves with the data, generating initial codes, searching for themes, reviewing the themes, defining and naming themes, and documentation [34]. The data taken from the previous field study [17] were then inductively analysed by the first three authors in our study to generate the initial codes. In a group discussion, the selected codes were further classified into more general categories of themes and then refined in a cyclical process. The subcategories were refined until they gave a representative picture of the data. To ensure the reliability of the data, all final decisions on categorization of the themes were reached by referring to the negotiated agreement approach. This method is described by Garrison et al. [35] and was supported with the help of consensual coding [36]. Based on the identified themes, a literature review was undertaken. This allowed us to analyse any scientific background and potential content for science learning that could be associated with and explored using ISc. In order to search the scientific background of the identified ISc, we used scientific literature search systems such as Google Scholar, Science Direct, Web of Science, and National Center for Biotechnology Information (NCBI) and using peer reviewed literatures from the search results. The literature search and analysis was conducted in 2018. Because most ISc knowledge dealing with natural resources is related to derivatives from indigenous plants, the literature for the scientific background for the indigenous plants was very limited. Our search techniques employed keywords that were combined with the Latin name of the plants related with the topic or theme of indigenous science resources in the Baduy community that we found in the field study. For example, we use the keywords “biopesticide from Noni fruit (*Morinda citrifolia* L.)” that related with the theme of agriculture. This allowed us to find related articles that discussed the scientific explanations and benefits of these plants. For other themes, the keywords used were as follows: medicine (“phytochemicals in *Orthosiphon aristatus*”); household cleaning materials (“phytochemical of soap nuts or *Sapindus rarak*”); natural dyes (“natural dyes from *Indigofera tinctoria*”); renewable energy (“renewable oil from *Pangium edule*”); astronomy (“ethnoastronomy in the Baduy tribe”).

Stage 2—Interpretation of contexts and content from ISc for SSI-based science education: For the discussion and interpretation of the data, science content and contexts related to the curriculum were reviewed. These included the exploration of local wisdom, values, and the foci of ESD. Based on information about the scientific background information on ISc, we could identify content in the science curriculum. The content was then analysed using both the syllabus for Indonesian upper secondary schools and an introductory, university-level science textbook. We explored local wisdom and sustainability values of the ISc topics by identifying the Baduys’ philosophical ideas, cultural elements, and values with regard to sustainability. This step included an analysis of social demands within an educational design framework, so that we could incorporate ISc into science education as was suggested in Zidny et al. [16]. Local wisdom and sustainability values found in ISc are essential when considering the educational significance of possible learning content, especially if these aspects are culturally bound. After this, the ISc content and contexts identified within the Baduy community were discussed using the five criteria for selecting sociocritical, problem-oriented issues for science teaching [19] in relation to a context-based, socioconstructivist pedagogical approach (see [18]). This analysis identified potential ISc topics having sustainability aspects that could be taught in science classes (Figure 2).

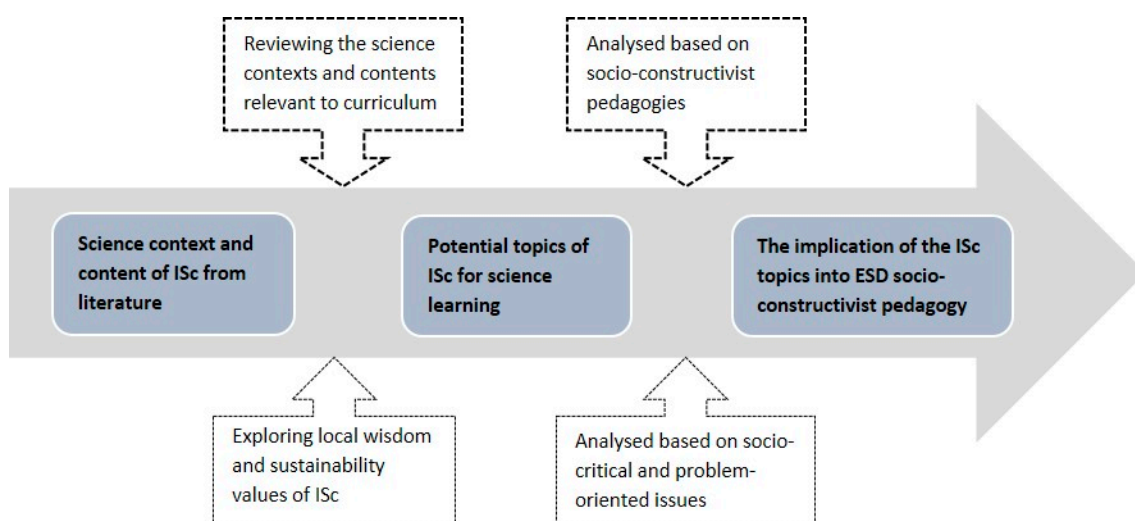


Figure 2. Analysis for incorporating indigenous science (ISc) into sociocritical, problem-oriented issues.

4. Results

Our field research on the Baduy community [17] revealed a lot of ISc-related knowledge that could offer learning contexts and contents for science. The data analysis identified six different themes (see Table 1). Scientific explanations were then derived from the literature as key information (e.g., [37]) in order to identify content that could be contextualized for science learning in secondary and higher science education. As shown in Table 1, the ISc-related knowledge of the Baduy community aligns closely with several modern, Western science concepts. Thus, ISc provides local contexts to approach science concepts from a Western viewpoint. Both views complement each other in this instance and can provide benefits for learners of socioculturally contextualized ESD. Based on the curriculum coverage in Indonesian curricula for secondary schools and college level education, it is suggested that different educational levels fit with the related science content.

Table 1. Six themes of the sociocultural context of science in the Baduy community.

Themes	ISc of the Baduy Community	Science Background	Related Science Content	Suggested Educational Level
Agriculture	The Baduy community uses plants as biopesticides to control pests in their rice plantations: Noni fruit (<i>Morinda citrifolia</i> L.), <i>Momordica charantia</i> , <i>Achasma walang</i> , <i>Bridelia monoica</i> .	160 phytochemical compounds in Noni fruit have been explored for possible benefits, such as antiviral, antifungal, antibacterial, or antinematode function [37].	Chemistry: organic compounds, pesticides, phytochemistry, chemical analysis Biology: classification of plants, bioactivity of compounds, bioassay, biodiversity	Higher education and upper secondary school
Medicine	Some medicinal plants are used by the outer Baduy community to treat different diseases. For example, <i>Orthosiphon aristatus</i> , a species in the family of Lamiaceae is used [32].	Phytochemicals in <i>Orthosiphon aristatus</i> have been isolated, which have antidiabetic, anti-inflammatory, antioxidant, hepatoprotective, analgesic, and nephroprotective activity. These include terpenes, organic acids, and flavonoids [38].	Chemistry: phytochemistry, chemical analysis, organic chemistry Biology: biodiversity of medicinal plants, classification of plants, bioassay, bioactivity of compounds	Higher education and upper secondary school
Natural dyes	Craftsmen in Baduy society use natural dyes from plants for their distinctive clothing (Batik Baduy) such as indigo from the leaf of <i>Indigofera tinctoria</i> .	Indigo is formed in damaged leaves by the oxidation of hydrolysis products of various precursors such as indican (indoxyl- β -D-glucoside) or isatan B (indoxyl ketogluconate) to indoxyl [39]. The process is affected by the activity of decomposing bacterial enzymes.	Chemistry: chemistry of dyes, chemical reactions, chemical extraction Biology: classification of plants, enzyme activity, natural dyes	Junior high and upper secondary school

Table 1. Cont.

Themes	Isc of the Baduy Community	Science Background	Related Science Content	Suggested Educational Level
Household cleaning materials	Lime (<i>Citrus aurantifolia</i>), soap nuts (<i>Sapindus rarak</i>), <i>Pteris vittate</i> , and <i>Mischocarpus fuscescens</i> are used for body cleaning products.	The pericarps of soap nuts (<i>Sapindus rarak</i>) contain saponins, high-molecular-weight glycosides consisting of a sugar moiety linked to an aglycone [40]. Saponins have detergent or surfactant properties, because they contain both water-soluble and fat-soluble components.	Chemistry: chemistry of detergents, solubility Physics: surface tension Biology: classification of plants	Junior high and upper secondary school
Renewable energy	The Baduy people have no access to electricity and fossil fuels such as kerosene for lighting. They extract the oil from the fruits of <i>picung</i> (<i>Pangium edule</i>) and make it into oil for lamps [32].	<i>Pangium edule</i> contains methyl esters that can be considered a future biodiesel source. This biodiesel produces cloud, pour, and cold filter plugging points of -6 , -4 and -8 °C, respectively. This shows the viability of using this biodiesel in cold countries [41].	Chemistry: organic chemistry, chemistry of biofuels Physics: environmental thermodynamics. Biology/biochemistry: enzyme activity in esterification reactions	Upper secondary school and higher education
Astronomy	The Baduy have culturally maintained the traditional calendar (<i>Pranata Mangsa</i>) for the swidden farming cycle (slash-and-burn agriculture). The most important constellations for the Baduy community are Orion (<i>Bintang Kidang</i>) and the Pleiades (<i>Bintang Kartika</i>).	The stars of the Pleiades usually appear two weeks before the appearance of Orion, when the sun is in the northern hemisphere. According to the Baduy, this is when the land is cold. In comparison, when Orion begins to set on the western horizon and cannot be seen, rice should not be grown, because the soil is hot, and many insect pests appear at this time [42].	Physics: astronomy, stars and the solar system, Kepler's laws of planetary motion, Newton's laws of gravity. Biology: plant physiology, swidden farming (slash-and-burn agriculture)	Junior high and upper secondary school

5. Discussion

Generally, indigenous people try to use their knowledge of nature in combination with the idea that humans should respect nature and the natural balance. They attempt to practically apply their knowledge without devastating the environment [5,16]. They use a variety of natural resources to fulfil their needs and consider the impacts their use may have on their future [5,17]. For instance, the Baduy community avoids synthetic chemicals both in agriculture and for daily living needs. As an alternative, they use natural products that are biodegradable in the environment, such as biopesticides in agriculture or natural clothing dyes [17]. This is an example of the application of sustainability principles in their life. They also use their knowledge to survive climate change. The ethnoastronomy knowledge that they apply to rice farming helps them overcome the impacts of seasonal weather swings during their agricultural planting period, thus avoiding crop failure. Such knowledge may provide fruitful contexts for science learning in connection with learning about culture and sustainability. The topic is based on the culture of the surrounding community, which is close to the lives of many Indonesian students. Moreover, students can learn from the perspectives of indigenous peoples and contrast them to Western views about how to use nature and how to solve the global challenge of sustainability [16].

The aspects of interdisciplinarity in science education can also be found in the learning process based on ISc. As shown in Table 1, each theme contains some interrelated learning content uniting the fields of chemistry, biology, and physics. Each topic is also related to questions about culture, ecology, and the local economy. This is in line with the learning approaches in ESD, which emphasize multi- or interdisciplinary problem-solving strategies [43] and the need for multisystem thinking [44]. Students learn to analyse SSIs from various perspectives of the scientific field and beyond. This allows them to obtain a more holistic view of the corresponding issue. For instance, in the context of learning about household cleaning materials, students can learn about the aspects of compounds and chemical reactions in soap-making. Moreover, they can also study soap quality parameters based on surface tension from the point of view of physics. Then, students can

simultaneously use biology to explore the classification of plants that naturally produce surfactant substances to locate a sustainable and economically benign resource.

In terms of local wisdom and philosophical aspects, the application of ISc by the Baduy meets the mutually agreed-upon principles and norms. It maintains the sustainable life of the community for both present and future generations. The Baduy people have a philosophy containing a determination (*pikukuh*) to preserve nature, that is, "... *gunung teu meunang dilebur, lebak teu meunang diruksak, lojor teu meunang dipotong, pondok teu meunang disambung ...*" ("... the mountain is not allowed to be destroyed, the river is not allowed to be destructed. If it is long, it is not allowed to be cut and if it is short, it is not allowed to be connected ..."). The essence of the Baduy idea is that humans are not allowed to change anything that can cause damage to nature. They are required to conserve their environment, described by protecting mountains, forests, and rivers, which are the main sources of life. Their purpose in life is to achieve an adequate, fair, prosperous, safe, and peaceful existence. Despite living under strict rules, they are born as independent people and uphold the values of honesty and discipline. This philosophy has become the life principle of the Baduy community to sustain their people. The philosophical aspects of indigenous peoples can provide new insights into accommodating the values of environmental ethics in science learning.

The field research performed by Zidny and Eilks [17] also revealed that the Baduy community has cosmological beliefs, norms, and cultural aspects from their ancestors that are concerned with protecting nature. They believe that land, forests, and other natural resources have a spirit, so they must protect their homeland. They will not let anything harm the ecosystem and the sacred forest where they live. In their agricultural system (upland rice planting), nine kinds of traditional rituals are predominantly undertaken by the Baduy community for management of the swidden farming system [33].

The Baduy people understand that the existence of their community not only depends on the sustainability of natural resources but also on the integrity of their culture. Figure 3 illustrates several activities that the Baduy people perform to fulfil their daily needs. Some taboos are additionally imposed in a social and cultural context in order to protect their norms, beliefs, culture, and behaviour from outside influences. The Baduy community has a unique traditional governance, which still exists to regulate their customs. In order to enforce customary laws and prevent violating taboos, various self-control mechanisms and social controls exist, including the imposition of punishment. Because of the local wisdom of the Baduy community, they can maintain the integrity of their culture. This aspect of local culture might become a new perspective in science education to foster intercultural understanding among students. It can also provide a different view of how societies might achieve sustainability.

The sociocultural context of ISc can be associated with sustainability education. The context found in learning has the chance to address both ISc and modern, Western knowledge. It can extend both knowledge systems and find values and new perspectives for teaching and learning [45]. The given context should help learners develop critical thinking and decision-making skills. These confront learners with the influence of ideological, cultural, and historical contexts of science [15]. In order to identify potential topics of ISc for ESD, the context of science from the literature presented in Table 1 was analysed based on socioconstructivist pedagogies [18]. Further analyses included the five criteria for selecting socioscientific issues for sociocritical learning (see [19]) and topical issues in ESD [11]. The potential topics are individually categorized and organized around the six themes (see Table 2).

All the topics identified from ISc can be connected to sustainability issues for learning (Table 2). They are authentic and relevant and not just for the Baduy community. These topics are open-ended and controversial with regard to whether behaviour in industrialized societies should change to more closely mirror Baduy ideas concerning sustainability. Each topic also deals with science and its applications. They all offer promising contextual approaches for science education. These contexts can be placed into an SSI teaching and

learning setting. This will encourage learners to compare the ISc of the Baduy community with modern, Western science and its related applications, when confronted with critical thinking situations.



Figure 3. The daily activities of the Baduy people (pictures were taken with permission).

Table 2. The potential topics for education from ISc of Baduy community.

Themes	Potential Topic	Sustainability Aspect to be Learned
Agriculture	Bio-rational control of pest insects using indigenous materials vs. synthetic pesticides	Learning about risk-benefit analysis between synthetic and green pesticides Green chemistry approaches to isolate and explore eco-benign pesticides
Medicine	Investing in research on traditional medicinal plants as starting points for chemical drug development	Comparison of risks and benefits regarding modern, Western and traditional medicine
Natural dye	Natural dyes from local plants: chemistry applications and sustainability assessment	Risks of chemical textile dyes and eco-friendly alternatives from ISc
Household cleaning materials	Using plant-based biodegradable compounds from ISc as household chemical	Addressing the issues of water pollution and considering alternative biodegradable household chemicals from ISc
Renewable energy	Oil lamp from ISc (<i>Pangium edule</i> Reinw.): A nonedible oil feedstock for biodiesel production.	Issues associated with fossil fuel use and renewable energy sources from plants
Astronomy	The role of ethnoastronomy to the determine rice planting and harvest times as a response to climate change.	Introducing the issue of climate change effects to the agricultural season and reflectively adapting land use to mitigate harmful effects by comparing ISc and modern, Western science.

We suggest that when the student is confronted with ISc, they must be involved in the discussion of controversial issues within a multiperspective, multidimensional view of science. The choice of context must consider the interest that the learner has in the topic. The teacher, however, has the role to provide the lesson plan and the relevant content and contexts for the course and offering a suitable pedagogical approach to allow students to follow both their interests and guidance in achieving the learning goals. The relevant aspects of science learning in the school curriculum should also consider the educational background level of students. For instance, junior high school students might prefer to choose topics such as synthetic and natural dyes or household chemicals, because they deal with smaller-scale, less complex societal controversies. On the other hand, themes such as the controversial use of pesticides or renewable energy sources deal with more complex issues. These seem more suitable for upper secondary school or undergraduate students with higher critical thinking skills. The implications of the context of science learning in ISc is more meaningful if it is associated with sustainability issues in SSI-based education. The emphasis on science learning is not only restricted to the process of content learning and contextual understanding. It might also promote the development of critical scientific literacy [46] and add to the level of intercultural understanding among learners [17].

6. Implications and Conclusions

In science learning, the integration of ISc as an SSI for ESD should be more than just teaching about the issue and the related problems. To deliver the issues, teachers need to encourage students to participate in active learning through student-oriented, cooperative learning or with the aid of inquiry-based science teaching [18,19]. The issues discussed in the learning process are complex and require problem-solving skills. For this reason, the role of the teacher is very important in describing problems in ESD from various perspectives at a level that students can understand. Educators must be able to connect personal actions and student questions to the process of developing solutions to those problems [18,27]. If applicable, the point of view should include perspectives both from ISc and Western, modern science. For instance, the lesson can facilitate the student to express their ideas and argumentation in inquiry learning related to sustainability issues (e.g., investigating harmful effects of pesticides use) by comparing different perspective from ISc and Western, modern science in search for alternative green pesticides [47]. This might allow the development of a more comprehensive understanding of the problem of sustainability, in local communities in particular and in the larger society in general. In addition, the teacher also should be able to interconnect the values of local wisdom and sociocultural and philosophical aspects of ISc and add them to the modern, Western view of science. This is certainly a challenge for educators in science education, since they are required to promote intercultural understanding within different cultural perspectives in science to foster ESD.

The sociocultural context of ISc can be an innovative educational approach in science education to promote ESD, especially in regions with strong cultural roots that differ from the West, such as parts of Asia, Africa, or Latin America. ESD is an educational perspective initiated by the UNESCO with a goal of global realization [48,49]. The application of ESD in science education has already started in developed countries such as Germany, Spain, and Canada, since the Decade of Education for Sustainable Development [50] was begun. For instance, the implementation of ESD in formal and non-formal education was conducted in Spain through citizen science initiatives [51] and programmes to inspire technological scientific vocations in an environment of equality and sustainability [52]. However, the application of ESD has not yet been optimal in developing countries, such as Indonesia. Based on a UNESCO report on ESD implementation [53], the ESD concept has been implicitly integrated into the educational system in Indonesia through programmes and activities relating to ESD. These include schools, university programmes, and activities related to ESD themes such as green school and green campus. However, ESD remains rather superficial in the science teaching and learning process in regular classrooms. This

is due to teachers and teachers-in-training not being sufficiently equipped with ESD knowledge to integrate ESD into their teaching practices.

The low level of ESD implementation in the case of Indonesia draws our attention to the existing curriculum in Teacher Education Institutes (TEIs). Indonesia has 12 public TEIs (Teacher Education Institutes) and more than 100 private TEIs spread throughout the country. These offer pre-service training for more than 700,000 student teachers, who constitute the majority (27.16%) of all university students [53]. These prospective teachers are potential initiators of change and potential future practitioners of ESD. They should learn how to incorporate ESD into their teaching without needing to make significant changes in the curriculum. Reorienting TEIs' focus implies empowering schools and teacher educators to develop ESD awareness on the part of students. To realize this, innovations to the educational curriculum can include introducing relevant contexts (such as those identified from ISc) to students, while at the same time promoting ESD through a sociocultural approach to science—raising sustainability issues belongs to this area. Such ideas can infuse values from local wisdom from ISc directly into the curriculum. The integration of ISc into science curricula would provide a different sociocultural context of science. This connects ethics, culture, and human philosophical aspects regarding nature, which offer a more holistic view of science to reach a sustainable society [16]. It also offers a socioscientific view of the different perspectives of science (ISc and Western, modern science) when finding strategies to achieve a sustainable lifestyle. Globally, this approach could add innovation to science education with regard to promoting ESD in developing countries.

ISc and other non-Western viewpoints of science offer a rich context that reveals the sociocultural aspects of science [16]. Contexts borrowed from ISc can be fruitful topics that can be tied to the science curriculum. This may help students learn science from a different cultural environment based on contexts that are close to real-life experiences [5]. This aspect can make science be perceived as more personal, meaningful, and relevant by students. Integrating views and contexts from ISc into science teaching has the potential to allow learning about the social implications of scientific knowledge. This ties in directly with the welfare of a given society, in our case the Baduy community in Indonesia. Integration of ISc into the science curriculum also provides a chance for dialogue and the consolidation of two different knowledge systems (ISc and modern, Western science). This offers the opportunity to merge the advantageous aspects of different world views in regard to sustainability [16] and to promote eco-reflective, relevant education for sustainability [6,54].

The analysis of science content and contexts from the ISc of the Baduy community that was conducted in this study offers a new way to show how to incorporate and reconstruct the valuable knowledge, culture, and local wisdom of indigenous peoples into the formal science curriculum. Since local indigenous wisdom and the sacred respect of indigenous peoples to nature are similar in many indigenous communities, this paper might also lead educators in other environments for investing in curriculum development with respect to their own indigenous living neighbours. Using this analysis, educators can be facilitated to bring relevant and authentic science into class that really is close to the student's cultural background and environment. This is an important chance for curriculum development, since it can provide meaningful contexts. Such contexts consider the relevance of science for life and development, while simultaneously promoting sustainability [14]. ISc provides a transdisciplinary view of sustainability, which aims to respect various ways of knowing things. Accordingly, this approach gives learners a broader view of the world. This allows them to understand both scientific knowledge and holistic views in order to better understand the role of social and cultural contexts in the production of scientific knowledge [20,55]. In this sense, the trans-disciplinary aspects of sustainability are viewed as a transformational stream of sustainability science [56]. This approach also provides a chance for science learning in an integrated way and encourages student's interest in science, technology, engineering, and mathematics (STEM), which is necessary for achieving better solutions to the global sustainability issues [52] and also might better include aspects of arts and the humanities in the future. Further research needs to dig deeper

into the knowledge base of indigenous peoples. Evidence-based curriculum development and research is needed to pinpoint and explore the full potential of integrating ISc into science education. In the context of the sustainable development goals (SDGs), this study focuses on several aspects, e.g., not only those SDGs focusing on the preservation of the environment and safe access to water and food but also those on equality and societal justice. The discussion about the culture and gender equitability as well as the equitable respect to ecological sustainability and protection of the environment social and economic issues in science learning is also an important aspect that should be explored in future studies in more detail.

7. Limitations

This study is necessarily limited, since its only focus on just one group of indigenous people in Indonesia. Further research might reveal whether similar examples are available in other countries where part of the population is indigenous, whether findings are similar or different. Limitations in our approach do arise, since this study is qualitative and interpretative in nature. This is, however, due to the circumstances caused by focusing on a community that is very different than the typical subjects of common educational studies. However, this can also be a strength, if we are seeking alternative viewpoints and perspectives to topics.

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