Socio-scientific Issues-based Science Education as a Promising Response to the Call for more Relevant and Societally Embedded Science Learning in Indonesia

DISSERTATION

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By

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OVERVIEW

The following dissertation is a cumulative thesis which consists of four articles and one book chapter. The articles are all written in English. Three articles have been published in international journals for science education research, one article is under review, a book chapter was published in the book of collection of invited papers by the 24th Symposium on Chemistry and Science Education held at the University of Bremen, in June 1-3, 2018. The first 3 articles are based on studies regarding socio-scientific issue (SSI)-based education in Indonesia, which involved science teachers, either in-service science teachers (ISTs) or pre-service science teachers (PSTs). These studies serve as empirical base derived from the experience and view of teachers for the needs to develop SSI-based science teaching materials which support the SSI-based education movement in Indonesia. As the follow up of the empirical studies, an SSI-based teaching unit using an Indonesian context was developed and implemented.

The first and second studies are respectively about the ISTs and the PSTs experience and views regarding SSI-based education. The challenges that were considered barriers for teachers to incorporate SSIs in their science teaching in class and potentials of SSI-based instruction in Indonesian school settings, particularly about the students' and the teachers' competencies that can be enhanced, as well as the students' characters that can be developed through SSI-based education, were explored. In addition to that, topics potentially of value to incorporate SSI-based instruction according to teachers' views were identified. Furthermore, the teachers' intension to implement SSI-based science instruction in their teaching despite the potential challenges and focusing benefits of corresponding teaching practices was explored. The third study is a case study about the PSTs teaching experience in using daily life contexts when they teach in their teaching internship program. How the PSTs taught environmental pollution, which can be considered as highly related to SSIs, was investigated. Furthermore, whether or not the PSTs taught the topic in an SSI-based teaching fashion was explored. The fourth study is about the implementation of an SSI-based teaching unit using palm oil-based biodiesel in Indonesia.

According to the first three studies, involving ISTs and PSTs, the teachers rarely teach under SSI framework. Moreover, at their teacher education program, PSTs never learned about the SSI-framework during their courses. The teachers acknowledged some challenges to conduct SSI-based instruction, such as students' lack of competencies, teachers' lack of experience and expertise in SSI-based teaching, the curriculum constrains, as well as time limitations. However, the teachers had positive views about the students' competencies and characters that can be enhanced through SSI-based education. Despite all the challenges and potentials of SSI-based teaching in their eyes, the teachers would like to implement SSI-based instruction in their classes. The third study showed that SSI was not intentionally used in the PSTs lesson plans nor in the teaching practices although the PSTs considered that the topic of environmental pollution fulfilled the characteristic of SSIs. By the result and discussion of these three studies, it is suggested that science teaching based on SSIs should be more taught at the teacher education programs, either in the pedagogical or the science courses. By giving the science teacher candidates experience on how science class is undertaken in the light of SSI-based instruction, it is hoped that it will increase their knowledge, experience, and expertise about SSI-based education and serves as their reference how to integrate SSI-based teaching when they will become a teacher in the future. For that reason, an SSI-based teaching unit derived from the palm oil-based issue in Indonesia was developed and implemented to the PSTs at a chemistry unit. The student teachers clearly gave positive feedback about the teaching unit. As another SSI, the thesis suggest the topic of genetically modified rice.

ZUSAMMENFASSUNG

Die folgende Dissertation ist eine kumulative Arbeit, die aus vier Artikeln und einem Buchkapitel besteht. Alle Artikel sind in englischer Sprache verfasst. Drei Artikel wurden in internationalen Fachzeitschriften für naturwissenschaftliche Bildungsforschung veröffentlicht, ein Artikel wird derzeit überprüft, ein Buchkapitel wurde im Sammelband zum 24. Symposiums zur Chemie- und Naturwissenschaftsdidaktik veröffentlicht, das vom 1. bis 3. Juni 2018 an der Universität Bremen stattfand. Die ersten drei Artikel basieren auf Studien zu gesellschaftlich relevanten naturwissenschaftlich Themen (socio-scientific issues; SSIs) im Unterricht in Indonesien, an denen naturwissenschaftliche Lehrkräfte beteiligt waren, entweder aktive NaturwissenschaftslehrerInnen (ISTs) oder NaturwissenschaftslehrerInnen in Ausbildung (PSTs),. Diese Studien dienen als empirische Basis, die aus den Erfahrungen und Ansichten der Lehrkräfte abgeleitet wurden, um SSI-basierte wissenschaftliche Unterrichtsmaterialien zu entwickeln, die die SSI-basierte Bildungsbewegung in Indonesien unterstützen sollen. Im Anschluss an die empirischen Studien entwickelte und implementierte ich eine SSI-basierte Unterrichtseinheit für Indonesien wichtigen Kontext der Biodiesel-Nutzung.

Die erste und zweite Studie befassen sich jeweils mit den Erfahrungen und Ansichten der ISTs und der PSTs bezüglich SSI-basierten Unterrichts. Die Herausforderungen, die als Hindernisse für LehrerInnen angesehen wurden, SSI in ihren naturwissenschaftlichen Unterricht zu integrieren, und die Potenziale des SSI-basierten Unterrichts in indonesischen Schulen, insbesondere die Kompetenzen der SchülerInnen und LehrerInnen, die verbessert werden können, sowie die Charaktere der SchülerInnen, die durch SSI-basierten Unterricht entwickelt werden können, wurden untersucht. Darüber hinaus wurden Themen identifiziert, die die LehrerInnen als potenziell wertvoll für die Integration des SSI-basierten Unterrichts erachteten. Zusätzlich wurde die Intension der LehrerInnen untersucht, SSI-basierten Naturwissenschaftsunterricht in ihren Unterricht zu implementieren, trotz der potenziellen Herausforderungen entsprechender Unterrichtsmethoden. Die dritte Studie ist eine Fallstudie über die Unterrichtserfahrung der PSTs bei der Verwendung von Kontexten des täglichen Lebens beim Unterrichten in ihrem Unterrichtspraktikum. Es wurde untersucht, wie die PSTs über Umweltverschmutzung lehrten, das als stark mit SSIs assoziiertes Thema angesehen werden kann. Weiterhin wurde untersucht, ob die PSTs das Thema auf der Basis einer SSnI-basierte Lehrmethode unterrichteten oder nicht. Die vierte Studie befasst sich mit der Implementierung einer SSI-basierten Unterrichtseinheit zu palmölbasiertem Biodiesel in Indonesien.

Laut den ersten drei Studien, an denen ISTs und PSTs beteiligt waren, unterrichten die LehrerInnen selten im Sinne eines SSI-Ansatzes. Darüber hinaus haben die PSTs in ihrer Lehrerausbildung selten etwas über das SSI-basiertes Lehren gelernt. Die LehrerInnen erkannten einige Herausforderungen bei der Durchführung von SSI-basiertem Unterricht, wie z.B. mangelnde Kompetenzen der

SchülerInnen und fehlende Erfahrung und Fachkenntnisse der LehrerInnen im SSI-basierten Unterricht, Einschränkungen durch den Lehrplans sowie zeitliche Beschränkungen. Die LehrerInnen hatten jedoch positive Ansichten über Kompetenzen und Charakterentwicklung bei SchülerInnen, die durch SSI-basierten Unterricht verbessert werden können. Trotz aller Herausforderungen und wegen der Potenziale des SSI-basierten Unterrichts in den Augen der LehrerInnen, möchten viele von Ihnen SSI-basierten Unterricht in ihren Klassen implementieren. Die dritte Studie zeigte, dass SSI weder in den Unterrichtsplänen der PSTs noch in der Unterrichtspraxis bewusst (vorsätzlich/absichtlich) eingesetzt wird, obwohl die PSTs der Meinung waren, dass das Thema Umweltverschmutzung die Eigenschaften einer SSI gut erfüllt. Aufgrund der Ergebnisse und der Diskussion dieser drei Studien wird vorgeschlagen, dass über den naturwissenschaftlichen Unterricht, der auf SSIs basiert, in den Lehrerausbildungsprogrammen mehr gelehrt werden sollte, entweder in den erziehungswissenschaftlichen oder naturwissenschaftlichen Kursen. Indem den KandidatenInnen zu NaturwissenschaftslehrerInnen Erfahrungen bei der Durchführung des naturwissenschaftlichen Unterrichts unter Berücksichtigung des SSI-basierten Unterrichts vermittelt werden, wird erwartet, dass sie ihr Wissen, ihre Erfahrung und ihr Fachwissen über SSI-basierten Unterricht erweitern und ihnen dies als Referenz für die Integration des SSI- basierten Unterrichts dient, wenn sie in Zukunft den Beruf des Lehrers oder der Lehrerin ausüben. Aus diesem Grund wurde eine SSI-basierte Unterrichtseinheit, die aus der SSI Palmöl-basierten Biodiesels in Indonesien abgeleitet wurde, entwickelt die Lehrerbildung implementiert. Die Lehramtsstudentinnen bzw. Lehramtsstudenten gaben eindeutig ein positives Feedback zu der Unterrichtseinheit. Als weiteres Thema wird zudem die SSI von Gen-modifiziertem Reis vorgeschlagen.

I. FRAMEWORK OF THE STUDIES

We are now living in the era of modern life in which our lives are influenced and dependent on the development of science and technology. On the one hand, science and technology development makes our lives easier, more practical, efficient, or even cheaper. However, it can also cause potential risk on the other hand, either in short term, or long term. Therefor the young generation should become knowledgeable about the implications of science and technology, able to deal with corresponding situations and make informed decisions about dilemmas caused by the development of science and technology. Let us take some examples about the dilemmas or controversies around the issue of genetically modified organisms, nuclear power plants use, vaccines, biofuels, etc. The viewpoints and decisions regarding those types of issues are not only based on scientific considerations, but incorporate other social factors, such as ethics, economics, culture, or moral questions (Sadler, 2011a). This type of controversial societal issue with conceptual links to science are called socio-scientific issues (SSIs) (Sadler, 2004). In this section, I will describe how SSI-based education can contribute to attaining scientifically literate generations, as well as its connection with education for sustainable development and relevant science education.

1.1 The SSI-based educational framework

In recent decades, there has been an increasing call to contextualize science learning through societally relevant questions (e.g Hofstein *et al.*, 2011). The SSI movement is one of responses to the call for the contextualization of science content through the exploration of socially relevant issues (Sadler & Dawson, 2012). Some scholars have argued that the advancement of the SSI movement is to feature socially relevant issues because it is underpinned by explicit theory (Sadler & Dawson, 2012), such as cognitive and developmental psychology (Zeidler *et al.*, 2005), constructivist theory (e.g., situated learning theory) (Greeno, 1998; Sadler., 2009; Sadler, 2011a) or , humanistic theory (e.g., Bildung theory) (Sjöström & Talanquer, 2014; Sjöström *et al.*, 2017; Sjöström & Eilks, 2018; Sjöström *et al.*, 2020; Sjöström & Eilks, 2020).

SSIs have the following characteristics (Zeidler & Nichols, 2009; Zeidler, 2015): (1) They are controversial. (2) They present ill-structured problems faced by society, which require not only scientific evidence-based reasoning, but also moral reasoning or ethical concerns. (3) They have social ramifications which require students to engage in discussion, dialogue, debate and argumentation. And (4) they are associated with character formation. SSI approaches provide a means to not only address societal implication of science and technology but also moral, ethical, emotional, and epistemological development of students (Zeidler *et al.*, 2005). Furthermore, Zeidler *et al.* (2005) also suggest that curricula which use SSIs provide an environment in which students become engaged in discourse and reflection which affect their personal cognitive and moral development.

One of the frameworks for SSI-based science education has been proposed by Sadler (2011b). According to this framework, SSI-based instruction consists of two core aspects, namely: *design element* and *learner experience*. The *design element* consist of four features: 1) Instruction is built around a compelling issue; 2) the issue is presented first; 3) scaffolding for higher-order practices is provided (e.g. argumentation, reasoning, and decision making); and 4) culminating experience is provided, which could be done through multiple pedagogies, such as role play, debate, service learning, etc. In the *learner experience* aspect, some essentials and experiences are suggested, such as engaging in higher order practices associated with the negotiation of SSIs, as well as confronting the scientific idea and theories, collecting or analysing scientific data, and negotiating the social dimensions related to the issue. The implementation of both core elements are shaped by the *classroom environment* and *teacher attributes*. Other SSI-teaching and learning models have been also suggested by Sadler and colleagues, e.g., see Sadler *et al*. (2017).

This is in agreement with another SSI-framework called socio-critical and problem oriented science education, developed by Eilks, Marks and others (e.g. Eilks, 2002; Marks, Bertram, & Eilks, 2008; Marks & Eilks, 2009, 2010). According to this framework, teaching should be started with a current, controversial, societally-relevant, and authentic issue from the society which allows the students to learn science content, whereas at the same time engages them into group discussions and decision making processes. Under this approach, a fruitful socio-scientific issue meets some specific criteria. The issue is authentic and relevant, since it is controversially discussed in the media with different points of view, such as TV news, newspapers, advertisements, podcasts, etc. It should allow for open debate in the classroom in which arguments from science and technology may play a role. SSI- based science education is suggested to start with authentic media leading via science learning into decision making exercises.

SSI-based instruction has become an effective means for students to contextualize their science learning within a multifaceted societal and political context (Hancock *et al*., 2019). Constructivist theory stresses the importance of contexts for the students to experience meaningful learning (Greeno, 1998). Furthermore, Sadler (2009; 2011a) argued that according to situated learning theory, environments or contexts (e.g., SSIs) in which the students learn are very important and formed by the learners themselves as the result of their interaction and participation with the context. These contexts, in turn, shape the way how the participants engage in activities, influence what the participants know and are able to do. SSI- based approaches provide a context for the students to confront some of the controversial societal issues linked to science and technology (Sadler, 2011a).

Under SSI-based education, there are calls for the strategies which enable students to make informed decisions, analyze, synthesize, and evaluate different sources of data and information, use moral reasoning to ethical issues, and understand the complexity of connections inherent within contextualized science learning (Zeidler *et al*., 2019). The ability to make a thorough and informed decision regarding SSIs is an important feature of scientifically literate individuals (Zeidler & Lewis, 2003; Zeidler *et al*., 2005)

1.2 Scientific literacy as the learning goal of science education

Ever since the 1960s, the goals of school science education in many countries have shifted from a primary focus on preparing the next generation for science- related careers to achieving scientific literacy for all (Eilks *et al*., 2013b). Scientific literacy has been suggested to be one of the major goals of science education (Sadler, 2011a), particularly scientific literacy which is more societal-oriented (Eilks *et al*., 2013b). Although the definition of scientific literacy and what it should cover, are under constant debate (Laugksch, 2000; Roberts, 2007; Sjöström & Eilks, 2018), most of the available definitions includes the societal dimension as an indispensable part of scientific literacy (Belova & Eilks, 2016). The integration of the human and societal dimensions in the chemistry curriculum is also advocated by other scholars (Sjöström, 2013; Sjöström & Talanquer, 2014; Mahaffy, 2015).

Roberts (2007, 2011) distinguished two vision of scientific literacy. Vision I focuses on the prominence of scientific content and processes for later application, particularly for science-related jobs or future education, whereas Vision II stresses the importance of science learning from meaningful contexts to understand the usefulness of scientific knowledge in life and society. Recently, a third, critical view that places emphasis on the development of general skills for personal and societal development through science education was suggested (Sjöström *et al*., 2017; Sjöström & Eilks, 2018). Vision III of scientific literacy suggests to use controversial, authentic socio-scientific issues as the driver for the curriculum in science education in order to highlight emancipation and socio-political participation. This vision was inspired by the humanistic tetrahedron proposed by Mahaffy (2004), which was enriched by recognizing different level of complexity in the analysis of humanistic aspects in chemistry education (Sjöström, 2013; Sjöström & Talanquer, 2014). This vision is influenced by the critical version of *Bildung* which aims to enhance scientific literacy for societal participation as a self-determined and responsible citizen (Sjöström *et al*., 2017; Sjöström & Eilks, 2018; Sjöström, Eilks , & Talanquer, 2020; Sjöström & Eilks, 2020). This perspective is necessary, but often missing in science education (Hofstein *et al*., 2011; Zeidler, 2015).

Another part of scientific literacy for the 21st century that has been acknowledged is character formation and values education (Choi *et al*., 2011; Sjöström & Eilks, 2018). Character formation and values are assumed to be driving forces that serve as general points of reference for individuals to make responsible decisions regarding local or global SSIs (Choi *et al*., 2011; Lee *et al*., 2012). SSIs have been suggested as a vehicle which can help promoting character formation and values education for global citizenship (Lee *et al*., 2013). Science education should be therefore linked to character-building education (Berkowitz & Simmons, 2003).

Over the last few decades SSIs have been suggested and proven to be the main driving force of the promotion of scientific literacy within the science education community (Hofstein *et al*., 2011; Zeidler, 2015; Zeidler *et al*., 2019). According to the most recent definition of PISA, there are three competencies featured by scientifically literate persons, namely: 1) the ability to explain phenomena scientifically; 2) the ability to interpret data and evidence scientifically; 3) the ability to evaluate and design scientific inquiry (OECD, 2018). A SSIs framework is critical to foster students to achieve the scientific literacy competencies identified by PISA (Powell, 2021). In addition to those competencies advocated by PISA, SSI frameworks also promote students' moral and character development (Zeidler, 2014, Owens *et al.*, 2017) which become critical in encouraging students to make thorough decisions on issues which require morality (Powell, 2021).

It is believed that scientifically literate individuals should be capable in making informed decisions about socio-scientific issues which are faced by modern, technologically advanced societies (Zeidler & Lewis, 2003). Scientific literacy is the ability to functionally act as a responsible citizen within society, either at home, work, or in the community (Holbrook & Rannikmae, 2009). The needs for scientifically literate citizens is also in line with the intention of education for sustainable development.

1.3 Education for Sustainable Development

Our modern world has brought us to a series of societal and or environmental problems which urges everyone on this planet to live in a sustainable fashion. In addressing the issue of sustainability, it is suggested to bring all the views of associated stakeholders together, including policy makers, scientists, and the private sector (Zuin *et al.*, 2021). A global initiative, Education for Sustainable Development (ESD) was established by the United Nations Conference on Environment and Development in order to promote sustainable development and enhancing the capacities of the people to address environmental and developmental issue (UNCED, 1992). Thus, the years between 2005 to 2014 were announced as the Decade of Education for Sustainable development (DESD) by the United Nations (UNESCO, 2005). ESD then scaled up by the Global Action Program on ESD which was designed as a real contribution to development and education programs after 2015 by integrating sustainable development into education or vice versa (UNESCO, 2014). Furthermore, in 2015 at the 70th Session of the United Nations General Assembly, the 2030 Agenda for Sustainable Development was adopted, which set 17 Sustainable Development Goals (SDGs) (UN, 2015). Quality Education is one of the standalone goals (SDG 4) which aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030, as well as the means to attain the other SGDs (UNESCO, 2017). There are ten targets as the guidance for the countries for a transformative way to a sustainable education agenda, among them is Target 4.7

"ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development" (UN, 2015, pp. 17).

Education has fundamental roles in SDGs implementation: as a main driver of human development, and powerful tools of implementation across all the SDGs by serving as a vehicle to grow awareness, enhance knowledge, and build up capacity of players around the world to show active roles to attain the 2030 Development Agenda (UNESCO, 2018). Education can promote knowledge, skills, values, and attitudes that individuals need to empower themselves to contribute to sustainable development (UNESCO, 2017). ESD as a teaching approach encourages sustainability consciousness among students, enhance knowingness of ecological issues and also students´ self-report increased behaviour in response to ecological issue (Pauw *et al*., 2015). ESD aims at empowering learners to take informed decisions and responsible actions for environmental integrity, economic feasibility, and an equitable society for presents and future generations (UNESCO, 2017). Therefore, ESD empowers learners so that they can think, act, and live in a sustainable and responsible manner. How ESD is addressed in the curriculum, teacher training program, development of teaching and learning materials, and the learning environment is the key to framing the effective application of ESD (UNESCO, 2018). In order to support ESD in the curriculum, it is suggested to integrate ESD across all subjects, as well as to provide professional development (Laurie *et al*., 2016)

In order to integrate ESD in science education in general or chemistry education in particular, Burmeister *et al*., (2012) identified four models, namely: 1) Green chemistry principles are adopted to the practice of science education practical work; 2) Sustainability strategies are added as content in chemistry education; 3) Controversial sustainability issues are operated to drive chemistry education; 4) Chemistry education is integrated as a part of ESD-driven institutional development. All the four models can contribute to the learning *about* or *for* sustainable development. However, the third and fourth are the most promising modes to integrate education for sustainable development, in which mode 3 is easier to implement because of practical reason (Burmeister *et al*., 2012). Through SSI-based education, the idea of education for sustainable development can be combined with the questions of the relevance of science education (Eilks & Hofstein, 2014).

1.4 Relevant science education

Science and science education are not very popular among many students (Hofstein *et al*., 2011). Traditional science learning is often considered as being irrelevant among the students (Holbrook, 2005). School science curricula are suggested to be overloaded and too much exclusively focusing learning of facts and theory (Gräber, 2002; Lyons, 2006). As a result, students can hardly connect the facts and concepts they learn with real life applications, thus they do not recognize the personal relevance of science learning to their lives (Stuckey *et al*., 2013) and society's future (Eilks & Hofstein, 2015). Consequently, they may fail to participate in discussions on societal issues regarding science and technology (Hofstein *et al*., 2011).

Some studies indicate that students are more interested in science when they perceive the topics to be personally relevant (Bybee & McCrae, 2011). What is perceived to be relevant by the students is, however, not always in line with what the teachers consider (De Jong & Talanquer, 2015). Therefore, science teachers are required to make their teaching more relevant from the perspective of the student and of society, so that their students' interest and motivation in learning science are maintained (Eilks & Hofstein, 2014). Some studies show robust evidence for an encouraging relationship between SSI-based instruction with the promotion of key learning outcomes, including student interests (Sadler & Dawson, 2012). Therefore, science teaching should be transformed from less relevant, content based into relevant, contextualized teaching (Eilks *et al*., 2013b). Childs et al., 2015 suggested some ideas to connect everyday contexts to school science curricula and to make science more relevant, including a focus on everyday life objects, everyday materials, everyday activities, everyday issues, and other area of interest, such as art and culture.

Stuckey *et al*. (2013) suggested a model of understanding relevant science education which covers intrinsic and extrinsic components and consists of three different dimensions, namely individual, societal, and vocational relevance. Among the three dimensions of relevance in science education, the societal dimension is often the most neglected one (Stuckey *et al*., 2013, Hofstein *et al*., 2011). A socio-scientific issues (SSI)-based approach is suggested to best increase ESD (Burmeister *et al*., 2012), as well as integrating the three dimensions of relevant science education in teaching (Eilks & Hofstein, 2014).

II. STUDIES ON THE INDONESIAN EDUCATIONAL BACKGROUND

2.1 The needs for incorporating SSI-based instruction in Indonesia

According to the result of the Program of International Student Assessment (PISA), Indonesian students' scientific literacy remains among the lowest tier of teaching success (Argina *et al*., 2017). In order to enhance students' scientific literacy to reach the Vision III suggested by Sjöström and Eilks (2018), there needs to be a way to simultaneously make students skilful and get ready to be engaged actively in socio-scientific controversies (Sadler, 2004). In line with character formation and value education as a part of scientific literacy (Choi *et al*., 2011; Sjöström & Eilks, 2018), the Indonesian government has explicitly emphasized the need for moral character development through formal and informal education as stated in the Peraturan Presiden Republik Indonesia Nomor 87 Tahun 2017 (2017). Science education is suggested to have an important role in promoting character building in formal education, for example through the implementation of an SSI-based instruction (Nida *et al*., 2021a).

The incorporation of SSI-based pedagogy in science teaching is also supported by the emerging agenda about strengthening the curriculum with the needs to achieve 21st century skills among students, along with fostering ESD as stated in the strategic plan published by the Indonesian Ministry of Education and Culture (Kementerian Pendidikan dan Kebudayaan, 2018, 2020). According to the result of a study which analysed the extent to which the ideas of SDG 4.7 were embodied in policies and curricula across 22 Asian countries, including Indonesia, the competencies such as critical thinking, empathy, and collaboration which are associated with SDG 4.7 are already incorporated into education policy and curriculum (Mochizuki, 2019). However, the study revealed that those competencies are more valued for enhancing national economic growth, rather than as attributes of global citizens. Moreover, according to the content standards (Kementerian Pendidikan dan Kebudayaan, 2016a), as well as core and basic competencies (Kementerian Pendidikan dan Kebudayaan, 2016b) for science junior secondary education by Indonesian Ministry of Education and Culture, the issue of sustainable development (e. g. through SSI-based learning) is not explicitly articulated.

Furthermore, the Indonesian Ministry of Education has recently made a reformation in the national assessment which explicitly highlights higher order thinking skill and literacy (Kementerian Pendidikan dan Kebudayaan, 2019). Through this policy, teachers are expected to change their assessment and teaching practice into more competence based and stresses higher order thinking skills as well as literacy. The assessment policy, together with the needs for scientific literacy, character education, education for sustainable development have called for a more relevant societally embedded learning in Indonesian science teaching practice (e. g SSI-based education).

Analysing the implementation of SSI based learning around the world, Genisa *et al*., (2020) conclude that the implementation of SSI-based instruction is mostly conducted in developed countries, including the United States, Germany, Sweden, or Japan. In Indonesia, however, the implementation is limited (Genisa *et al*., 2020, Subiantoro, 2017). This is parallel with the findings by Nida *et al*., (2020, 2021b), that most science teachers' rarely incorporate SSI-based pedagogies in their teaching practices. Moreover, the majority of the teachers are not familiar with SSI-based education. The student teachers regularly have not received knowledge on SSI-based education during their teacher education courses (Nida *et al*., 2021a).

2.2 Indonesian science teachers' views about SSI-based education

Prior to developing and implementing an SSI-based teaching unit, three studies were conducted as the basis of evidence on Indonesian science education practices in the means of a needs analysis for the development and enactment of SSI-based instruction. In order to explore Indonesian science teachers' views about SSI-based learning, particularly to its challenges and potentials to be implemented, two studies were conducted. The first study (Nida *et al*., 2020) was administered to 99 in-service science teachers (ISTs) from various schools in Eastern Java, Indonesia, whereas the second study (Nida *et al*., 2021a) was focusing 62 pre-service science teachers (PSTs).

According to both studies, the challenges which commonly referred to by the teachers are students' lack of competencies; teachers' lack of knowledge, experience, expertise; and curriculum constrains. Different from ISTs who put students' ability to be the first place challenge, PSTs mentioned the multidisciplinary/multi-perspective nature of SSIs to be the most challenging factor hindering implementation of SSI-based instruction. The teachers also acknowledged some potential competencies that learners might develop when implementing SSI-based pedagogies, such as communication, problem-solving, critical thinking, higher order thinking skills, scientific inquiry, etc. In addition to that, the teachers recognized several competencies that teachers might develop by SSI-based instruction, which are mostly related to pedagogic skills, such as designing innovative contextual learning, classroom organization, teaching skills, and utilising various learning resources for teaching.

The teachers expressed positive views on the contribution of SSI-based learning in enhancing students' character formation. Some character aspects that the teachers mentioned to be developed by SSI-based pedagogies included environmental and social awareness, open-mindedness, responsibility, etc. When being asked about their willingness to implement SSI-based teaching, they expressed willingness, at least to some extent. Whether or not the teachers' positive views and intensions will lead to implementation of SSI-based education must be viewed with caution, since it faces many hindering factors.

As the follow up of the study involving PSTs, a case study was conducted to explore the use of daily-life contexts and socio-scientific issues when PSTs took their teaching internship in their final year (Nida *et al*., 2021b). According to this study, the PSTs mostly used daily-life contexts related to objects and everyday issue related to society and the environment. However, the contexts were generally used for motivational purposes and for student engagement with science concepts. The PSTs didn't used the contexts to provoke societal discussions, although they acknowledged that many contexts related to environmental issues can be used in the sense of SSI-based pedagogies and were considered to potentially provoke discussions beyond science. The positive views of the PSTs on SSI-based education shown in a previous study (Nida *et al*., 2021a) did not automatically make them implement corresponding approaches when they teach science (Nida, *et al*., 2021b). This could be possibly due to the perceived challenges that the PSTs mentioned in the previous study.

2.3 Bridging the gap

The studies (Nida *et al*., 2020 & Nida *et al*., 2021a) showed that the teachers perceived SSI-based teaching and learning as a promising field, in spite of some challenges that might hinder the practise of SSI-based pedagogies. Therefore, science education research and development should invest in designing SSI-focused learning resources and commitment to continuous professional development in Indonesia. From the sample of the study conducted by Nida *et al*. (2021b), it seems clear that a focus on SSI-based pedagogies would enrich teacher education programs. The study suggests not only teaching about corresponding pedagogies by lecturing, but also mimicking classroom situations with the PSTs by thoroughly implementing SSI-based education in PST education programs. For those reasons, the development of a SSI-based intervention using the Indonesian context and implementing it in a chemistry unit for a PST education program was started. A case study was done to examine the suitability of the current controversial issue of palm oil-based biodiesel production in Indonesia (Nida, *et al*., under review). The study looked at how the issue was used as a teaching context in undergraduate chemistry education and to investigate the students' views about the developed lesson plan.

III. TEACHING INTERVENTION

3.1 Palm oil-based biodiesel use in Indonesia as an SSI teaching context

The issue of palm oil production is highly controversial and became subject of a strong political and environmental debate (Obidzinski *et al.*, 2012). The controversies about palm oil use for biofuels is not only authentic to Indonesia, but also internationally. When we check the online media search engines, palm oil use can be considered a hot topic of debate in public.

Biofuels use, such as in the form of biodiesel derived from vegetable oil crops and animal fat, has been promoted to be an alternative source of energy by many governments across the world as a response to the issue of climate change (Mukherjee & Sovacool, 2014). According FAOSTAT (2020), from 2008-2018 Asia accounted for 85.6 % of worldwide palm fruit production, with Indonesia and Malaysia as the two largest producers. As the biggest source of vegetable oil, palm oil became a promising source of biodiesel production. In Indonesia, small holder farmers produce more than 40% of all palm oil (Glenday & Paoli, 2015). Some studies have suggested that the development of palm oil in Indonesia has brought a significant benefit to rural communities and contributed to alleviate poverty (Rist *et al.*, 2010; Sandker *et al.*, 2007). However, this means that up to 60% of palm oil production happens under industrial conditions, with the corresponding risks of deforestation, monocultures and intense land use. The palm fruit agriculture's impact on natural forest habitats can result in biodiversity loss which endangers rare species, such as Orang Utan (CNN, 2017). Together with that, there is significant environmental impact in the life cycle of palm-oil-based biodiesel, including effects on global warming, eutrophication, acidification, and the synthetic chemicals release to the environment (Manik & Halog, 2013).

Critics to palm oil-based biodiesel sustainability is also voiced because of the negative effects on the well-being of local or indigenous peoples, who have been living in the rain forest for centuries (Manik *et al.*, 2013; Colchester *et al.*, 2006). According to the study by Manik and colleagues (2013) and through personal interviews with the tribal communities, the tribes said that they become marginalized as soon as the forests will be opened for plantations. They not only lost their land and were contaminated by polluted water, they also experienced the loss of intangible cultural heritage.

In spite of environmental issues about palm oil production, palm fruits are considered as the most effective plants for vegetable oils production, if compared to other sources such as rapeseed, sunflowers, or soy beans (Karmakar *et al.*, 2010). According to the data in their studies, palm oil is five to six times more productive regarding land use than the other feedstocks. We can infer that five to six times more land is required for to produce other feedstocks so that the same amount of oil compared to palm fruit is yield. Since the EU has excluded palm oil as a sustainable biofuel feedstock, the EU must satisfy its vegetable oil demands with other sources. This means the use of extra land acreage to plant non-palm fruit oil sources. A change from palm oil to other kinds of oil crops will not always give positive outcomes for biodiversity (Meijaard *et al.*, 2018). It is, nevertheless, not the purpose of the EU to replace palm-based biofuels, but to reduce their total use.

Furthermore, biodiesel blended with fossil based fuels has been considered to be one way to reduce exhaust gas emissions such as hydrocarbon and carbon monoxide (Abed *et al*., 2019; Gad, *et al*., 2018), as well as smoke opacity and carbon dioxide (Abed *et al*., 2019). These studies indicate that biodiesel is an alternative type of biofuel, which may decrease greenhouse gas emissions. However, an increase of NOx emission is also reported by some studies (Abed *et al*., 2019 ;de Araújo *et al.*, 2013), which can contribute to acid rain.

Despite the pros and cons of biodiesel technology, Indonesia established a mandatory biodiesel program since 2008 (Ditjen EBTKE, 2019). It was started in 2008 with a 2.5% biodiesel mix in fossil-based diesel, which gradually increased to 7.5% in 2010, 10% to 15% in the period of 2011 and 2015, and 20% in 2016. By the end of 2019, the Indonesian government launched the B30 mandatory program with 30% biodiesel blends. The biodiesel mandatory blending was established in order to fulfil the government's commitment to reduce greenhouse gas emissions from fossil-based fuels and cut the country's dependency on the imports of fossil-based fuel. By the beginning of 2020, the implementation of B30 just started in Indonesia. Biodiesel policy in Indonesia has been widely reported on by many news outlets. It has become, once again an intense topic of discussion in society and the media.

3.2 Developed pedagogies

The SSI of using palm oil to produce fuels is suggested useful for science learning in context. According to De Jong (2008), learning contexts may function as a motivation, orientation, illustration, or application of concepts. The palm oil-based biodiesel issue meets each of these functions, since palm oil production is an authentic issue in the Indonesian society and is frequently discussed in the media. It can enhance the relationship between science and students' everyday lives. This can motivate students to learn science. The topic also offers personal, societal, and vocational relevance to the students by highlighting and illustrating important practices and professions found in agriculture and industry. Palm oil use can also illustrate why students should learn about the science concepts behind growing and processing palm fruits for the production of oil and related products. There are a number of scientific concepts which can be integrated into the palm oil controversy. For example, undergraduate chemistry concepts which can be integrated can be related to organic compounds and reactions, particularly carboxylic acids, esters and trans-esterification. These content is important for teaching about biodiesel production and was already suggested on a lower level for the context of Germany in German upper secondary chemistry education (Eilks, 2002). Vegetable oils, including palm oil, are fatty esters, a group of organic compounds based on glycerine. During biodiesel production, the glycerine esters are transformed into methanolic esters with the aid of catalysis. Thus, the palm oil issue is suggested to motivate students to learn the science content behind it. This includes the structure, nomenclature, isomers, and properties of the carboxylic acid and esters. Other issues include the various oil extraction processes, transesterification for biodiesel production, etc.. At the undergraduate level, more details can be focused on when compared to the lesson plan suggested by Eilks (2002).

Furthermore, the issue can orient students with respect to societal discussions. Teaching the science concepts behind biofuel use is also connected to the societal question of whether or not to keep this technology or to switch the transportation sector over to other alternatives, such as solar- and wind-based energy. SSIs like palm oil-based biodiesel can easily illustrate the close, multi-faceted ties between science, technology, and society (Zeidler *et al.*, 2011). Lesson plan openers can come from authentic media (Marks & Eilks, 2009) such as the news media or YouTube, as has been suggested by Zeidler *et al.* (2011). The pros and cons regarding palm oil-based fuels can be used to engage students in higher-order thinking skills. This is because a discussion of the risks and benefits of palm oil is based on various perspectives, including science, economy, health, the environment, legal ramifications, etc. The topic can aid students in understanding how policy decisions are made. Such decisions are not only based on scientific reasoning, but also on moral aspects and questions of sustainable development. Students can be taught how to critically weigh the risks and benefits, so that they can make an informed decision regarding whether or not they should support the Indonesian government's palm oil biodiesel policy. In the end, learners can reflect upon science concepts and evaluate how they are used in societal decision making (Marks & Eilks, 2009). The context can also serve as an arena in which the students learn to accept and appreciate other peoples' points of view and develop open-mindedness. This issue can also enhance their sensitivity and awareness of problems faced by one society with regard to the viewpoints of other societies (Dawson, 2011). In general, the issue discussed here is expected educate students to think critically and to make responsible, informed decisions. Critical thinking and decision-making abilities are necessary skills for students to be actively involved in societal discussions as scientifically literate citizens (Zeidler *et al.*, 2011).

Another aspect of scientific literacy that can be enhanced through SSI-based learning is the question of the nature of science (NOS) (Wong *et al.*, 2011). According to Holbrook and Rannikmae (2007), NOS dimensions include understanding of both the NOS and the method of scientific inquiry. The palm oil issue can provoke students to conduct scientific inquiry examining the scientific as well as the societal aspects of the issue. Through the scientific inquiry process, the nature if science is also stressed (Lederman *et al.*, 2013). Scientific knowledge is understood to result from observations of the natural world, which includes human imagination, inference, and creativity and is socially and culturally embedded. The controversial nature of palm oil use as a fuel can show learners that different people have different opinions about using palm oil as source of biodiesel. This depends on which aspects they emphasize most. Another feature of NOS which this highlights is that the perception of scientific arguments is subjective.

3.3 Implementation and evaluation of the teaching module on biodiesel

3.3.1 Intervention

Table 1 lists the learning purposes and class activities used to introduce the SSI of palm oil-based biodiesel. There are some parallels to the lesson plan already suggested by Eilks (2002). New features implemented in this unit were a jigsaw puzzle learning model (Eilks *et al.*, 2013a) and the use of an online forum. The learning activity was conducted in three face-to-face meetings of 150 minutes each, in addition to an one online activity used as an introduction and expert group phase. In the introduction phase, the controversy about palm oil-based biodiesel in Indonesia was presented to the students with the help of authentic media. The students were provided with links to different types of media like a YouTube video called “Bye bye petroleum, say Hi to palm oil” published by CNBC Indonesia. In addition, the students were guided to a website criticizing the Indonesian palm oil industry for environmental reasons. The students were also given an online newspaper article about the Indonesian government's plan to implement B30 by January of 2020. The introduction to the unit was meant to push the discussion towards both scientific concepts and the societal aspects of biodiesel use (Eilks, 2002). Each student was asked to propose questions, either related to the science (chemistry) aspects or the societal aspects of the biodiesel topic.

Then the students were divided into eight home groups of four students each for the jigsaw model. Each student in the home group had one specific subtopic to learn and several assignments regarding the science aspects. The introduction and expert group discussions were conducted in an online forum using the university learning management system. The home group discussions were performed in the first face-to-face meeting. This was done to confront the students with the topic prior to having the class discussion and also for reasons of time management. The follow-up activity consisted of the lab work that was conducted in the second face-to-face meeting. Role-playing, debate, and decision-making activities were conducted in the third and final meeting.

Table 1. Learning purpose and activity in the unit focusing palm oil use (Nida et al., under review)

Phase	Description	Learning purpose	Learning activity
Introduction	The palm oil-based biodiesel issue is presented at the beginning of the unit in order to engage students with the issue	• Students are able access authentic media related to the biodiesel production issue • Students generate questions concerning the issue	Analysing authentic media about the biodiesel policy in Indonesia, e.g. from YouTube, is presented to the students Students are directed to formulate questions about chemistry content or societal aspects which they want to know or explore

Expert group discussion	Since vegetable oils are esters of fatty acids and glycerine, and biodiesel is made of fatty acid methyl/ethyl esters, the context of palm oil-based biodiesel controversy is used to orient the students to learn about carboxylic acids, esters, and particularly the transesterification process for biodiesel production.	Students are able: • to identify and draw the structure of carboxylic acids and esters. • to name the structures of carboxylic acids and esters. • to analyse the trend in the properties of carboxylic acids and esters and relate the structures of the compounds to their properties. • to draw the structure of oil derived from different types of fatty acids. • to identify the reactant, product, and process during esterification. • to identify the reactant, product, and process of transesterification. • to design laboratory work for biodiesel preparation using oil commonly found from daily life. • to examine the properties of biodiesel. • to examine the effect of biodiesel or its blends in term of exhaust emission and environment impact.	The students are divided into home groups as heterogeneously as possible with four students in each group. Each student in the home group has one subtopic to learn. All people with the same subtopic from each home group form expert groups. Within the expert group, the students discuss and answer the questions related to their specific subtopic. The expert group discussions were conducted in the online forum (four online groups total). Expert group A: Structure, properties, structural isomers, and nomenclature of carboxylic acids. Expert group B: Properties, and isomerism of esters Expert group C: Structure and nomenclature of esters, as well as the esterification and transesterification reaction. Expert group D: Properties of biodiesel and biodiesel's effects on exhaust emissions and the environment.
Home group discussion	The students are directed to return to their home groups to explain the concepts they learned in the expert groups and to discuss the other questions of the home group together.		After discussion in the expert groups using an online forum, each person returns to her or his original home group in order to explain the concepts they have just learned. After each student explains her or his part, the home group discusses the questions related to all of the subtopics. The home group discussions and the following activities are conducted in a face-to-face format.
Lab work	The students were asked to produce biodiesel using vegetable oils commonly found in their daily lives.	• Students are able to conduct practical work to produce biodiesel. • Students are able to explain the reactions in the process of biodiesel synthesis.	Each group conducts the lab activity to prepare their own biodiesel.
Role-playing, debate,	Students were reoriented with the biodiesel issue in order to discuss the	• Students identify the pros and cons given by different groups from within society	Each home group is assigned a role to play which represents a potential group in society. Each group is free to choose any role. However, four

decision making	societal aspects of the issue.	such as small farm holders, the palm oil industry, WWF, or Greenpeace. • Students are able to presents arguments in the role-playing exercise and debate session. • Students are able to make an informed decision about whether or not to agree with the Indonesian government's plan to increase biodiesel blends.	groups should represent be pro and the other four groups should be con. Each group is given several days to discuss the topic and write an essay about their own position to justify and defend their position during the debate session. In the debate session, each group presents their position and their arguments for the position based on the results of their analysis. Students make personal decisions regarding to their (dis)agreement with the government's plan to increase the biodiesel blend by weighing multiple aspects, including not only scientific, but also societal factors. Students propose potential win-win solutions to the problem.

3.3.2 Methods of feedback gaining on the module

The study was conducted between October and November of 2019 at a public university in Eastern Java, Indonesia. There were 90 undergraduate students majoring in science education from three different classes in their third semester who participated in the study. This took place as part of a course on "Elements and compounds" in a course focusing on organic compounds and reactions. All classes were taught by the author of this thesis.

Data collected included both a questionnaire and interviews. At the end of the meeting, the students were asked to voluntarily complete a questionnaire about their opinion of the unit. A total of 74 students responded to the questionnaire. The questionnaire consisted of twenty-eight, five-step Likert items, with answers ranging from strongly agree to strongly disagree. The questions focused on the participants' views about their motivation during the lesson, the perceived relevance of the topic, and on how the biodiesel issue was used in the unit. Some of the questions were adapted from Zowada *et al.*, (2018). Other questions were developed according to frameworks for SSI-based education (Presley *et al.*, 2013, Sadler, 2011b). The data was analysed descriptively as has been suggested for this kind of developmental oriented practical research (Bodner, MacIssac & White, 1999). Numbers and percentages were then calculated for the results.

The questionnaire results were enriched by semi-structured interviews with eleven of the students after they completed the questionnaire. The interviews were purposely constructed to complement the findings in the questionnaire about the students view regarding the developed pedagogy. The interviews lasted for 15-20 minutes. Each interview was audio-taped, transcribed and qualitatively analysed. From the responses to the questions in the interview, common themes/categories were inductively constructed according to Mayring (2014). Finally, two researchers coded the interview transcripts independently with an agreement rate of 95%. The disagreement were again discussed among the coders until 100% agreement was achieved.

Additional data used for illustration came from classroom observation notes taken by the teacher, as well as the students' learning artefacts. The participants provided the on a voluntary basis. All data collection and handling complied with the legal regulations for ethical empirical research with human beings at the department in question. Permission for data use was provided by the dean of the faculty.

3.3.3 Findings

3.3.3.1 Students' views about their interest and the relevance of the lesson plan

Students feedback about their interest and the relevance of the lesson plan is presented in Figure 2. A majority of the students considered the issue to increase their interest to learn science content as well as the societal aspects related to it. The students also acknowledges biodiesel to be an interesting topic and they enjoyed learning the chemistry behind it. In addition to that, the unit was considered to help them answering questions related to the chemistry of biodiesel and its associated societal aspects. Most of the students acknowledged that biodiesel topic was perceived relevant and interesting, particularly at university level. However, the students didn't give similar view if the topic is to be covered in high school science. The students' answer in the questionnaire were supported by the interview results.

Figure 2. Students' feedback about their interest and the perceived relevance of the issue (Nida et al., under review)

3.3.3.2 Students views of how the issue was covered in class

Students views about how the issue was covered in class is presented in Figure 3. In general, the students considered that the teaching unit has engaged them in higher order practices which enable them to enhance their skills and character formation. These views are also in agreement with the result from the interview.

Figure 3. Students' view regarding how the biodiesel issue was covered in class (Nida et al., under review)

3.4 Conclusion

The SSI of palm oil as a basis for fuels is an authentic, controversial issue in the country of Indonesia. It is directly related to science and societal aspects which can be used as a teaching context, through which students can view palm oil usage with a broader lens. The findings in this study suggest that SSI-based instruction on biodiesel is viewed as motivating, relevant, and encouraging when students are learning about the science (chemistry) elements and the societal implications of the issue. This falls in line with several previous studies focusing on the chemistry of biofuels in a broader, societally-oriented approach with an enriched pedagogy (e.g., Eilks, 2002; Feierabend & Eilks, 2011). In the current case study, changes in the curriculum and an enriched pedagogy were carried out in parallel. From the data collected, it seems that both changes were very positively perceived by the participating students. A novelty effect may also have played a role, but such an effect cannot explain the overwhelmingly positive responses given by the students.

In general, this study shows that authentic and controversial SSIs can be a positive stimulus to get students to learn chemistry. This study is one of the first in the educational context of Indonesian undergraduate chemistry teaching and teacher education. As such, it provokes further research questions about the effectiveness of content learning and the development of the necessary educational skills mentioned above. It also requires the development of further studies, how they might be implemented, and how they can be transferred to the secondary school teaching level. Further research and evidence-based curriculum development are needed, as is the professional development of teachers to help them incorporate SSIs into chemistry education (Mamlok-Naaman *et al.*, 2018) and into the educational context of Indonesia. Sustainability-oriented SSIs, e.g. on biofuel usage, have repeatedly proven their potential to enrich chemistry learning by focusing not just on learning about chemistry itself, but also on its societal and political implications (e.g., Eilks, 2002; Feierabend & Eilks, 2011; Mamlok-Naaman *et al.*, 2015). This remains a neglected field in the teaching of chemistry, both at the secondary school and undergraduate level, particularly in the case of Indonesia. Further research and curriculum innovation is needed in this areas.

This study has several inherent limitations. It is specifically bound to the educational context of only one university in Eastern Java and examined in only three classes. It focuses on a single topic in a specific pedagogical setting limited basically to the students self-reports. The feedback of the students is, however, so clear that it points out a clear direction for needed change in Indonesian chemistry teaching and teacher education. Therefore, it might be useful to develop further examples and to look deeper into this kind of intervention cases studies, by broadening the practice fields involved and by using multi-facetted evaluation and assessment approaches.

IV. SUMMARY

According to the framework that has been discussed in section 1, SSI-based learning plays an important role in enhancing scientific literacy, integrating education for sustainable development, as well as making science learning relevant. The first three studies (Nida *et al*., 2020, Nida *et al*., 2021a, 2021b) serves as the empirical evidence of the needs to implement SSI-based learning in Indonesian science education. The studies indicate that SSI-based learning is still rarely implemented by teachers in Indonesian science education settings. The perceived potential of SSI-based education to enhance students' and teachers competencies, as well as to enhance character formation should be reinforced by overcoming the challenge that might hinder the teachers to incorporate SSI-based pedagogies when they teach. The result of the studies give some implications, among them are: 1) There is a need to include SSI-based education in related pedagogy courses of the PSTs education program so that the PSTs obtain an adequate conceptual framework about SSI-based education. 2) SSI based instruction should be incorporated in potential science topics. And, 3) it is needed to make the teachers more knowledgeable, experienced, and expertized to implement SSI-based learning. SSI-based education should be covered also in the continuous teacher professional development of science teachers in Indonesia.

As a response to the call for more SSI-based integration in science classes, a SSI-based instruction on biodiesel use in Indonesia was developed (Nida et al, under review). By incorporating SSI-based instruction using potential SSIs in science topic, it is hoped that the PSTs become more familiar and get more experience as their reference to integrate SSI-based teaching when they later teach. The findings in this study suggest that SSI-based instruction provides positive views regarding motivation and relevance of the developed teaching unit when the students learn the chemistry aspects and the social implications behind the biodiesel issue. Further research about the effectiveness of the developed lesson plan and how it could be translated into science units for the secondary level is needed. Other potential issues to enact SSI-based instruction should be developed in order to give more examples of how corresponding issues can be undertaken in science classes. One potential issue could be about genetically modified food as suggested by Nida and Eilks (2018).

V. PUBLICATION

Publications related to this thesis:

Nida, S., Rahayu, S., & Eilks, I. (2020). A Survey of Indonesian Science Teachers' Experience and Perceptions toward Socio-Scientific Issues-Based Science Education. *Education Sciences*, *10*(2), 39. https://doi.org/10.3390/educsci10020039

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Nida, S., Pratiwi, N., & Eilks, I. (2021) A case study on the use of contexts and socio-scientific issues-based science education by pre-service junior high school science teachers in Indonesia during their final year teaching internship. *Frontiers in Education*, 4(592870): 1-8 https://doi.org/10.3389/feduc.2020.592870.

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APPENDIX

PAPER 1

A Survey of Indonesian Science Teachers' Experience and Perceptions toward Socio-Scientific Issues-Based Science Education

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education sciences

Article

A Survey of Indonesian Science Teachers' Experience and Perceptions toward Socio-Scientific Issues-Based Science Education

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Abstract: This survey explored Indonesian science teachers' experience and perceptions toward science teaching that is based on socio-scientific issues (SSIs). The participants were asked whether or not they already used corresponding practices in their own teaching and whether they experienced any challenges in implementing SSI-based pedagogies. Further focal points were the teachers' views on student competencies that can be fostered through SSI-based education, the connection of SSI-based pedagogies with students' character formation, potential topics for implementing SSIs in science education, and the teachers' interest in such implementation. Data were collected with the help of a questionnaire that was administered to 99 science teachers. This was then followed up by interviews with 20 intentionally selected teachers taken from the overall sample. The study revealed that teachers' familiarity with SSI-based pedagogies varies greatly. Regardless of their familiarity with the term, some of the teachers had already implemented corresponding practices at varying levels of intensity. Although almost all of the participants saw potential in SSI-based pedagogies for increasing student competency development and character formation, most of the respondents did not implement SSI-based teaching very often in their lessons. They mentioned several challenges that hindered them in implementing SSI in their teaching practices. Reasons included the lack of necessary students' competencies, a lack of teacher expertise, the content in the official curriculum, inadequate facilities, and a lack of time for lesson preparation and implementation. When asked for ideas in implementing SSI-based education, teachers basically suggested topics related to the environment or technology as suitable for SSI-based education. In spite of the many challenges, most of the teachers were still interested in implementing SSIs in their classes.

Keywords: science education; scientific literacy; socio-scientific issues; teachers' perceptions

1. Introduction

1.1. Background

Relevant science education focuses on the enhancement of scientific literacy among learners, which covers a broad range of goals [1]. Exactly what modern, scientific literacy-oriented teaching should include, however, is under constant debate [2]. Roberts described two visions of scientific literacy [3]. Roberts' first vision focuses on the conceptual understanding of science content for later application, e.g., in science-related professions. The second view stresses the fact that science learning should be contextualized in order to understand how meaningful science is for life and society. Recently, Sjöström and Eilks suggested a third, critical view that highlights the development of general skills for personal and societal development through science education [2].

The results of the Program of International Student Assessment (PISA) indicated that Indonesian students' scientific literacy remains among the lowest tier of teaching success [4]. In order to promote students' scientific literacy to reach the third vision by Sjöström and Eilks [2], there needs to be a way to simultaneously make students competent and prepare them to be involved actively in socio-scientific controversies [5]. Zeidler and Lewis believe that scientifically literate individuals should be able to make informed decisions about socio-scientific issues (SSIs) that are regularly faced by modern, technologically advanced societies [6].

Science education is significant when preparing future citizens to make informed decisions about science-based discourse in the modern world; therefore, learners should be facilitated with the environment (or context) to practice all the skills they require to be actively involved in SSI discourses, as well as learning the science content behind a given issue [7]. Science educators need to consider the context created for learners when they experience science in school [8]. However, teachers often introduce science topics with only oblique references to the everyday lives of their students [9]. Socio-scientific issue (SSI)-based learning provides relevant contexts that students might need to confront, negotiate, and decide upon in everyday-life situations linked to science and technology [7]. SSI-based education is not only a specific form of context-based learning for science education but also a framework promoting general educational skills for preparing students in order to be actively involved in a democratic society where they need to make informed decisions about SSIs [10]. This direct link to societal issues is, however, still neglected in many countries [11].

In Indonesia, SSI-based teaching can be considered as a new instructional approach in science education, so that there is a need to know how teachers perceive this teaching innovation [12]. Subiantoro recently conducted a study on the implementation of SSI-based instruction in Indonesian senior secondary schools [12]. He examined biology teachers' perception regarding SSI-based instruction. The results of the study showed that before participating in a teacher professional development program about SSI based-instruction, the teachers considered SSI-based pedagogy as a new concept. However, after taking part in the SSI-teaching professional development program the teachers had a basic insight on the necessity of SSI-teaching and deepened their knowledge about the advantages and challenges in implementing SSI-based teaching. To date, no further surveys on the situation in Indonesia concerning SSI-based science education are available. This is also true for Indonesian junior secondary science education (grades 7–9). The present survey explores science teachers' views regarding SSI-based teaching and learning in Indonesian junior secondary schools. It focuses on how practicing teachers in Indonesia perceive SSI-based pedagogies with regard to their potentials and challenges in grades 7–9.

1.2. Theoretical Framework

Zeidler provides several useful characteristics of fruitful SSIs [13]. They should contain: (1) controversial and ill-structured problems that require scientific, evidence-based reasoning to make informed decisions; (2) social ramifications for scientific topics that require students to get involved in dialogue, discussion, debate, and argumentation; (3) implicit and explicit moral aspects requiring, at least to some degree, moral reasoning skills; and (4) factors associated with the formation of personal virtue and character as a long-range pedagogical goal. Marks and Eilks [14] have previously suggested several criteria for selecting fruitful SSIs for science learning. These include authenticity, relevance, a controversial character, openness to debate, and relatedness to science and technology. Based on SSIs developed using these criteria, the socio-critical and problem-oriented approach to science teaching was described by Marks and Eilks [14]. Several case studies showed how skills necessary for developing critical scientific literacy, such as communication and evaluation skills, can be developed among learners [15–18]. Such skills are very important in educating responsible citizens for the future [11]. Moreover, SSI-based science education is a microcosm within society, in which discourse, argumentation, and decision-making represent important tools [19] for learners to develop cognitive, ethical, moral, social, and emotional skills [20]. In general, SSI-based instruction is one that utilizes SSIs as a focal point to drive the students to learn science aspects related to the issue, as well as to discuss any societal aspects.

SSI-based science education has the potential to foster personal cognitive and moral development in order to promote functional scientific literacy in students [13,21]. SSI-pedagogies exceed traditional teaching practices in the way that they encourage students to highlight multifaceted factors such as interpreting issues, making decisions, solving problems, and engaging in argumentation [21]. The controversial nature of SSIs can also be used as a tool to challenge students to suggest action and to recommend compromises or solutions based on scientific concepts [22]. It can also be used to justify learners' decisions, based upon normative beliefs related to ethical considerations [13]. In addition, Zeidler and Sadler have stressed that one of the long-term goals of SSI-based education is the formation of character [21]. Character formation under their SSI-framework is conscience-building, which is accomplished through a process of reflexive thinking.

There are some studies regarding teachers' perception about SSI-based pedagogies. Lee et al. examined Korean secondary science teachers' perception about introducing SSIs into the science curriculum [23]. The participants had positive views about addressing SSI's although only a few teachers operated SSI-based teaching in their classrooms. Moreover, the teachers mentioned lack of time and the unavailability of supporting materials to be the main difficulties that hindered them in teaching with an SSI-based approach. Challenges in implementing SSI-based teaching were also reported by Bosser et al. [24]. They described a conflict between implementing student-centered practices through SSI and the achievement of traditional learning goals.

The major challenge in implementing modern, student-centered teaching, including SSI-based instruction, in Indonesia is the strong emphasis on the national examinations. Teachers see difficulties between SSI-based teaching and the strong orientation on content knowledge in the curriculum to ensure students' success in the national examinations [12]. Nevertheless, Subiantoro described in the case of senior secondary biology teachers that despite all the challenges in implementing SSI-based instruction teachers are interested in SSI-based teaching because they consider students to become more motivated in science learning by SSIs [12]. Lee and Chang suggested two main issues of motivation in teaching along SSIs [25], one concerned higher motivation among teachers and the other motivational benefits among students. Yang et al. found that most science teachers believe that addressing SSIs in science classes is reasonable to cover elements of creativity and character formation [26].

To better understand the limited emphasis given to SSIs in junior secondary classrooms in Indonesia, this study aimed at examining Indonesian secondary science teachers' perception of SSI-based instruction and of teaching about SSIs in their classrooms. The guiding research questions in this study were:

1. Do Indonesian junior secondary science teachers incorporate SSI-based instruction in their teaching practices?
2. What are Indonesian junior secondary science teachers' views about incorporating SSI-based instruction in their classes?

To answer the first research questions, Indonesian junior secondary science teachers were asked whether or not they have known/read/heard about the concept of SSI-based teaching and, in case they have, what the source of information regarding SSI-based instruction was. The teachers were also asked whether/how often they have implemented SSI-based instruction in their classes. For the teachers' views on SSI-based teaching, the teachers were asked which competencies can be developed by SSI-based teaching among students and teachers, what aspects of students' characters formation might be enhanced, which topics are suggested to integrate SSIs in science education, and what challenges might hinder teachers in implementing SSI-based teaching. Finally, teachers' interest to implement SSI-based teaching in their science classes was explored.

2. Materials and Methods

2.1. Participants

This study was based on a questionnaire survey distributed to 109 participants of a science forum in East Java, Indonesia, in 2018. Ninety-nine science teachers of junior secondary schools voluntarily filled out the questionnaire. Following the questionnaire survey, interviews were conducted with selected teachers from the sample. After an initial screening of the questionnaires, 20 teachers were chosen based on the variety of their personal data and answers in the questionnaire. The interviews were conducted two weeks after the questionnaire survey in order to deepen the findings from the questionnaire.

In the questionnaire, the respondents were asked to describe their personal backgrounds, including teaching qualifications, teaching institutions, and teaching experience. The 99 teachers worked in 74 different schools and had varying educational backgrounds. Some of the participants taught in public secondary schools. Others worked in the private schooling sector. Nine of the teachers did not specify any affiliation. Details of the educational background, affiliation type, and teaching experience are given in Table 1.

Table 1. Background of the participants (N = 99).

Aspect	Profile	Number of Teachers
Educational background	Bachelor's degree (99) in:	
	Biology	19
	Biology education	36
	Chemistry	5
	Chemistry education	2
	Physics	8
	Physics education	22
	Science education	7
	Master's degree (38) in:	
	Biology education	2
	Physics education	22
	Science education	4
	Social education	1
	Management	5
	Chemistry	1
	Chemistry education	1
	Educational policy and development	2
School type	Private junior secondary school	31
	Public junior secondary school	59
	Teachers who did not specify the school affiliation	9
Teaching experience	0–5 years	32
	6–10 years	22
	11–15 years	23
	16–20 years	9
	More than 20 years	13

2.2. Questionnaire

The main part of the questionnaire concerned the teachers' views toward SSI-based science education. To provide an overarching definition of what SSI-based learning is, the questionnaire provided both a description and an example of SSI-based learning. SSI-based learning was defined as the pedagogy that utilizes controversial, complex issues related to science and technology; requires scientific and moral consideration; can be viewed from multiple perspectives and could have more than one possible solution. SSI-based teaching was described not only to direct students' learning of science concepts behind any given issue but also to deal with societal discourse, e.g., by analyzing pros and cons, assessing risks and benefits, and informing about decision-making. By the description and example of SSI-based teaching, it was assumed that the participants received a common point concerning the nature of SSI-based instruction.

The questionnaire was pretested with 34 teachers to guarantee the comprehensibility of the instrument before the study. The final questionnaire consisted of ten items, mostly open-ended (questions no. 4, 5, 6, and 8), and Likert-type questions (5 steps; ranging from "not at all/never" to "a very great extent/always"), depending upon the question (questions no. 3, 7, 10). The other types of questions included yes/no answers (question no.1) and multiple-choice formats with more than one potential response (questions no. 2 and 9).

The first three items in the questionnaire asked about teachers' personal experiences concerning SSI-based teaching. The next seven items regarded their views on the corresponding approaches. The questionnaire contained the following aspects:

(1) The teachers' familiarity (whether or not they have known/heard/read something) with SSI-based pedagogies
(2) Their source(s) of information,
(3) How often they had implemented SSI-based teaching,
(4) Any suggested challenges in implementing SSI-based teaching,
(5) Any student competencies that might be boosted by using a corresponding approach,
(6) Any teacher skills that can be developed,
(7) To what extent SSI-based teaching can contribute to character formation,
(8) Which aspects of character formation can be most significantly supported,
(9) Suggested science topics useful for implementing SSI-based teaching,
(10) To what extent the teacher remained interested in implementing SSI-based teaching in spite of any suggested challenges.

2.3. Analysis

All answers were transcribed and analyzed descriptively. The analysis of the open questions and the interview data was performed following the basic tenets of qualitative content analysis according to Mayring [27]. The responses to the open-ended questions were coded and counted according to categories inductively derived from the data. The analysis of the questionnaire data was later illustrated and enriched by responses from the follow-up interviews.

3. Results

3.1. Teachers' Experiences Regarding SSI-Based Teaching

The number of teachers who had never heard or read about SSI-based teaching and learning exceeded (53.3%) those who had previously heard about it (46.6%). At every level of teaching experience, more teachers were unfamiliar with the SSIs as an educational concept than those who had already heard of it, except the group of teachers with less than five years of teaching experience (Figure 1).

The teachers with previous knowledge about SSI-based teaching received their information from various sources. The two most common sources were colleagues and articles in teacher journals (each had a value of 41.9%). Other sources included workshops, the Internet, book chapters, and papers from teacher conferences (Figure 2).

Personal experience with implementing SSIs in science education also varied greatly. Almost 30% of the teachers had never implemented SSIs in their classes. Even among those who had previously heard of the approach, some had not implemented it. There were, however, some teachers who stated that they never heard about SSI-based education at the theoretical level but have used a corresponding approach in their classes. Altogether, a total of 64.6% of the participants never or rarely implemented

SSIs in their teaching, only 25.3% did so occasionally, and a mere 10.1% stated that they did so regularly. None of the teachers stated they used SSI-based teaching for the whole curriculum (Figure 3).

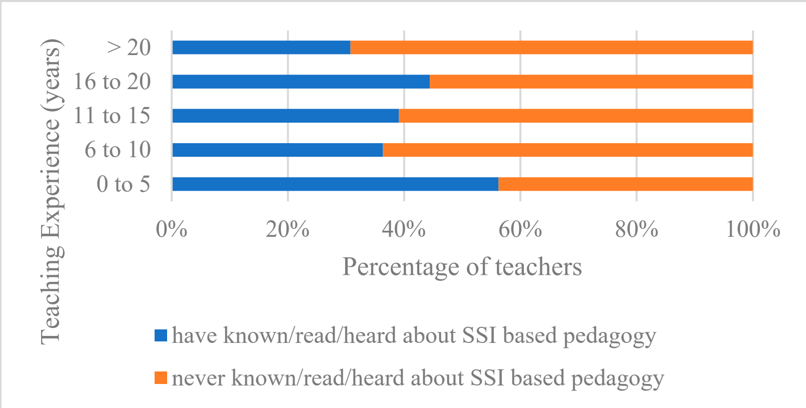

Figure 1. Teachers' general knowledge about socio-scientific issue (SSI)-based education.

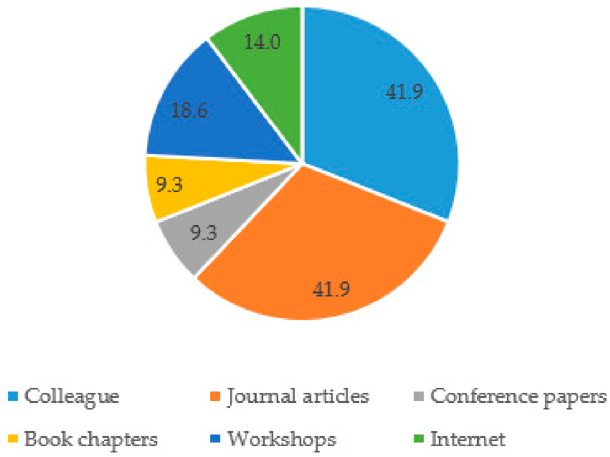

Figure 2. Sources of information on SSI-based science education.

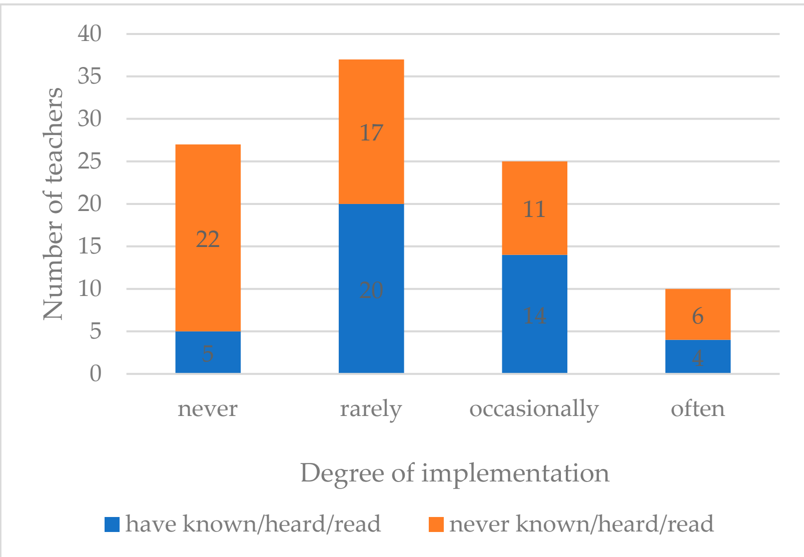

Figure 3. Frequency in implementing SSI-based learning.

A lack of implementation among those teachers who rarely/never implemented SSI-based learning in their classes might be generally caused by the focus of their teaching. For these teachers the science content seems to be the basic goal, not discussing any associated controversies, as stated in the following interview excerpt: *"I have used the food issue to talk about food ingredients, such as nutrients and food additives, whether the food is healthy or not. I ask the student to check the food ingredients on the label and to identify the function and risk of the ingredients. The discussion was mostly about the ingredients rather than any societal discussion. I also address the risk of additives, such as preservatives, coloring agents, sweeteners, etc., but we do not discuss any associated controversies."*

3.2. Teachers' Perceptions Regarding SSI-Based Science Education

The teachers suggested several ideas for competencies that might be developed through SSI-based learning, both for learners and teachers. These suggestions could be categorized into the areas of communication, problem-solving, critical thinking, scientific inquiry skills, social and environmental awareness skills, literacy, higher-order thinking skills, creativity, and collaboration skills (Table 2). A few competencies were mentioned by single teachers and included open-mindedness and curiosity.

Table 2. Suggested learner competencies that might be developed when implementing SSI-based teaching (% = teachers mentioning).

No.	Competence	Description	%
1.	Communication	Any response related to students' ability in communication, argumentation, discussion, or debate	33.3
2.	Problem-solving	Any response related to problem-solving	32.3
3.	Critical thinking	Any response related to critical thinking, reflection, or decision-making processes	23.2
4.	Scientific inquiry	Any response related to skills needed to conduct scientific inquiry	21.2
5.	Social and environmental awareness	Any response related to awareness of the environment or problems faced by the society	14.1
6.	Literacy	Any response related to literacy (reading, science literacy, scientific literacy)	12.1
7.	Higher-order thinking	Any response that covers higher-order thinking skills based on Bloom's taxonomy	12.1
8.	Creativity	Any response related to creativity	11.1
9.	Integrating science–technology–society	Any response regarding the ability to integrate science with life, technology, or society	10.1
10.	Collaboration	Any response about working together/collaboration	8.1

Aspects of communication and problem-solving are the skills most often suggested by teachers to be developed when SSI-based teaching is implemented, followed by critical thinking and scientific inquiry. One teacher stated in the interviews that students are very engaged in the SSI discussions: *"I used the issue about transgender in the topic of human growth and development . . . . The pro and cons within the society about transgender were very interesting for the students that their discussion was very intense, many students express their opinions and positions regarding the issue."* Concerning problem solving and critical thinking another teacher explained in the interview: *"For example, on the topic of environmental pollution, in this case, water pollution, as our school is located near a river polluted by waste such as plastic, I ask the students to propose ideas how to solve the problem. Some students thought of making the plastic waste into fuel . . . I also ask the students to reflect their daily activities which might contribute to river pollution, so that they can critically think of their habits and enhance their awareness to protect their environment."*

Aside from considering the skills that can be enhanced by learning about SSIs among the students, the teachers also considered some competencies that can potentially help the teachers themselves. These competencies tended to fall into seven categories: designing innovative contextual learning, developing teaching skills, acquiring interdisciplinary knowledge, utilizing varied learning sources, making authentic assessments, motivating students, and developing critical thinking skills (Table 3).

Table 3. Teacher competencies developed during SSI-based learning (% = teachers mentioning).

No.	Category	Description	%
1.	Designing innovative contextualized learning	Any response related to integrating daily life contexts to design and develop innovative science teaching	45.5
2.	Teaching skills	Any response related to teaching skills, including the ability to organize classes, manage time, etc.	24.2
3.	Interdisciplinary knowledge	Any response related to enhancing interdisciplinary knowledge, getting up-to-date information, etc.	12.1
4.	Utilizing varied learning sources	Any response related to organizing, utilizing, designing, or developing various learning sources	11.1
5.	Making authentic assessment	Any response regarding comprehensive assessments that cover all dimensions of learning	8.1
6.	Motivating students	Any response related to teachers' ability to motivate students to be more engaged in learning	8.1
7.	Critical thinking	Any response related to critical or reflexive thinking	7.1

Nearly half of the teachers considered that SSI-based teaching might enhance the teachers' ability in designing innovative contextual teaching, as also suggested in the interviews: "*Teachers would be more skillful in designing contextual learning based on specific problems which occur in their environment.*" The teachers also suggest that SSI-based science education can enhance their teaching skills: "*Teachers will be better at managing the class so that within the limited amount of time provided, the class can cover the material suggested by the curriculum. They can also educate their students to take care of and think about their societal problems.*"

Most teachers expressed positive views on the contribution of SSI-based learning on student character formation (Figure 4).

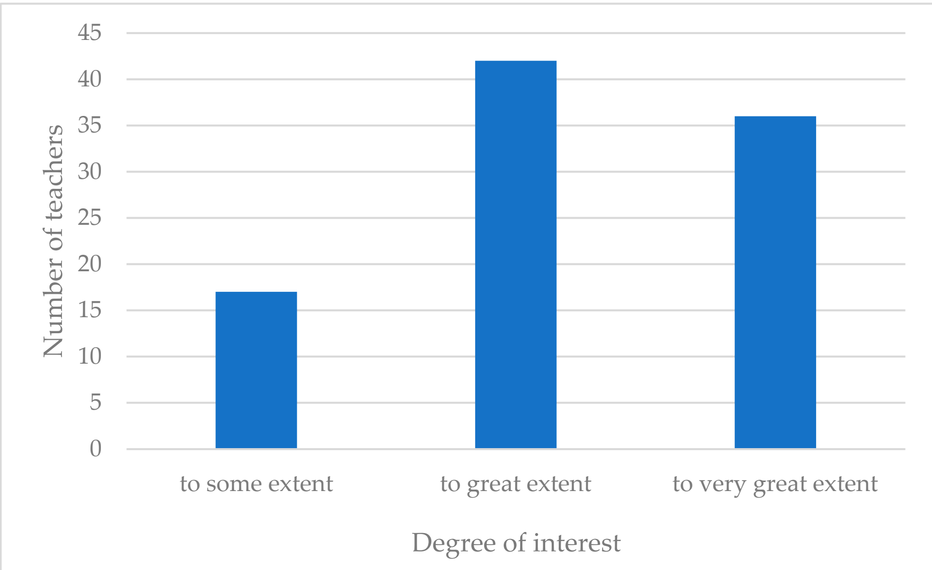

Figure 4. Science teachers' perceptions as to what extent SSI-based learning can contribute to character formation.

The aspects of character formation, which may be potentially supported by SSI-based learning, could be placed in seven categories. Environmental and social awareness were the two primary character traits prominently perceived as fruitful by the teachers for SSI-based learning. Other character aspects frequently mentioned were open-mindedness/respectfulness, responsibility, collaboration skills, critical thinking, positive attitudes, and consideration of values (Table 4).

Table 4. Character aspects that might be developed by SSI-based pedagogies.

No.	Category	Description	%
1.	Environmental and social awareness	Any response related to awareness of the environment, nature or society	34.3
2.	Open-mindedness/ respectfulness	Any response related to being open-minded and respecting other individuals or groups	15.2
3.	Responsibility	Any response related to decision-making or taking action in a responsible manner	12.1
4.	Collaboration	Any response related to working together or collaboration	11.1
5.	Critical thinking	Any response related to critical or reflexive thinking	9.1
6.	Good attitudes	Any response that shows implementation of positive attitudes in a general sense	9.1
7.	Considering values	Any response related to considering values, such as religious or cultural beliefs, ethical considerations, norms	6.1

The aspect of students' character formation that most of the teachers addressed, also in the interviews, to be potentially developed was environmental and social awareness: "*The students might be more aware about the issues in their environment or society, issues which are neglected*." The second often mentioned aspect of character formation was open-mindedness: "*Students have different opinions and are respectful to diversity. They might become open to different perspectives. Learners can communicate their opinions politely, based on evidence*."

Out of 33 science topics found in the Indonesian junior secondary school curriculum, some topics were seen as having potential for implementing SSI-based learning. Eleven potential topics were each suggested by more than 40% of the teachers. These topics commonly deal with the environment or technology (Table 5).

Table 5. The potential topics for SSI-based learning.

No.	Topic	%
1.	Environmental pollution	87.9
2.	Food biotechnology	81.8
3.	Global warming	77.8
4.	Addictive substances and additives	74.8
5.	Green technology	73.7
6.	Civilization and environment	50.5
7.	Interaction of living things and the environment	47.5
8.	Heredity	43.4
9.	Soil and life sustainability	43.4
10.	Energy and life systems	41.4
11.	The human reproductive system	41.4

The teachers, however, also described several challenges hindering them from implementing SSI-based education effectively. The responses were grouped into five categories, namely: lack of students' competencies, lack of teacher expertise, content in the curriculum, lack of facilities, and lack of time (Table 6).

Table 6. Challenge in implementing SSI-based learning (% = teachers mentioning).

No.	Category	Description	%
1.	Lack of student competencies	Any response related to students' lack of abilities/competencies/skills	32.3
2.	Lack of teachers' expertise	Any response related to the teacher's lack of knowledge, experience, and expertise	26.3
3.	Content in the curriculum	Any response related to the nature of the content in the curriculum or emphasis on teaching the content	25.3
4.	Lack of facilities	Any response related to facilities, including missing learning resources, or media	17.2
5.	Lack of time	Any response related to limited time	13.1

Lack of students' competencies is the most often suggested challenge in implementing SSI-based instruction, as also mentioned in the interviews: "*Most of my students are lower achieving students. It is difficult to engage my students in an active discussion. I have to make sure that they understand the science concept before involving them in the discussion about a societal issue like that*." Another point the teachers stressed about the students' reading abilities: "*I think this approach requires the students to read a lot of sources in order to understand the problem, but my students are not motivated and very poor in reading comprehension*."

Despite all the possible challenges to implementing SSI-based instruction, most of the teachers were interested in implementing SSIs in their teaching practice, at least to some extent (Figure 5).

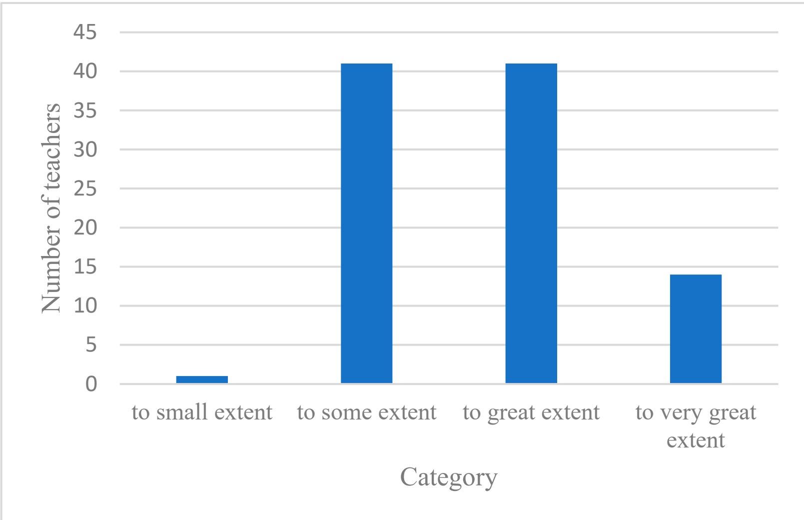

Figure 5. Science teachers' perceptions as to what extent they are interested in implementing SSI-based pedagogy.

From the interview, we also can see that many teachers were interested in implementing SSI-based teaching because they see a chance to enhance the relevance of science education, as well as to promote students competencies: "*I think I am interested to use SSIs in class because these issues are very relevant to students' lives. They can challenge students to be creative in solving problems from within the society*." Some teachers, however, were indifferent because this would be a new approach to teaching science to them. When asked in the interview about why they were interested in only some extent, one said: "*I think it is an interesting approach but I am not pretty sure how to use the SSIs in my class*." This quote supports the factor that hinders teachers to implement SSI-based learning, that is the teachers' lack of knowledge, experience, and expertise regarding the SSI-approach.

4. Discussion

It is likely that SSI-based pedagogies are known by only about half of the junior secondary science teachers from this sample in Indonesia. Even among teachers familiar with SSI-based education, most of them do not regularly apply them in their lessons. SSIs have become a focal point of science teaching since the end of the 1990s [28], but they are probably better known in countries outside Indonesia. SSIs have represented an emerging field in science education research in Western countries over the last decade. Researchers have provided many theoretical and conceptual justifications for including SSI-based pedagogies to achieve scientific literacy as the goal of science education [7] and developed corresponding didactic models [14]. Nevertheless, the application of SSI-based approaches is still limited even in Western countries because the primary goal of science instruction is still seen by many teachers as delivering science facts and theories [7]. In Indonesia, the SSI-based approach seems to have not been developed extensively and has had only limited influence on curriculum reform in science education [12].

The participants in the study acknowledged many competencies and skills that can be developed using SSI-based teaching and learning. This was believed to be true for both students and teachers. Using the framework outlined by Holbrook and Rannikmae, who proposed three domains of science education for enhancing scientific literacy [29], the skills suggested by the teachers covered the individual, societal, and nature of science domains. The individual domain includes aspects such as communication, critical thinking, literacy (in terms of reading competence), creativity, and higher-order thinking skills. Skills such as solving societal problems, social and environmental awareness, scientific literacy (in terms of applying knowledge for socio-scientific decision-making), interlinking science–technology–society, and collaboration could be linked to the societal domain. The nature of the science domain was also referred to in terms of scientific inquiry.

The teachers acknowledged the relatedness of SSIs to their students' lives and to society. They viewed SSIs as a way to help students, including lower-achieving students, become more involved in discussions, which can increase communication skills. SSI-based learning has previously been described in the literature as an enhancement of students' communication skills, such as the ability to relate ideas, to take stances, to be prepared for discussion, and to communicate a position [30]. It has also been suggested that SSIs can enhance levels of personal engagement and foster a greater sense of relevance among students [1,31]. There is hope that such teaching approaches can have a positive impact on students' interest because learners tend to be curious about SSIs in order to gain more knowledge about a given subject [32]. The teachers also recognized potential for enhancing collaborative and problem-solving skills. SSI-based approaches were suggested as a way to offer students further chances to engage in higher-order cognitive practices, such as argumentation, reasoning, and decision-making [33]. In this study, only a few of the teachers acknowledged the latter aspects, perhaps due to their limited personal experience. In the literature, it has been previously suggested that teachers should teach and actively practice higher-order thinking skills with their students if they want to develop them in their learners [34].

The participants also recognized several teacher competencies that might be developed, if educators use SSIs. Most of these abilities revolved around professional pedagogical skills, such as designing contextualized learning, utilizing and developing various learning materials, developing teaching skills, making authentic assessments, and motivating students. Teachers saw SSI-based instruction as a potential tool for designing contextual learning by integrating daily life contexts into lessons. They also stated that SSIs can be used to develop learning materials that are context-based and closely related to their students' personal needs. The teachers in this study suggested that SSIs can offer chances for more authentic teaching practices and assessments. This not only addresses the area of the assessment of knowledge but also includes the development of attitudes and other skills, including higher-order thinking skills. SSI-based teaching requires a broader, more highly integrated knowledge base borrowed from various disciplines. If teachers want their students to become critical thinkers, they need to practice such skills themselves.

The participants also believed that SSI-based education can positively contribute to character formation. Societal and environmental awareness are the aspects of character formation that were given the highest priority in this study. This falls in line with the literature, suggesting that ethical awareness and sensitivity can indeed be enhanced by SSI-based education [35–37]. Further aspects of character formation concerned open-mindedness and respect (see also [19,35]).

Constructing and delivering SSI-based education is a challenging undertaking by its very nature [38]. In our study, many teachers were skeptical of their students' abilities to participate in SSI-based discussions. They consider SSI-based education to be a big challenge. They suggested an overall lack of student competency in areas such as cognitive and reading skills. Many teachers listed this and other factors quite frequently when being asked about potential hinderances to SSI implementation. Analyzing PISA test results, Cromley found a high level of correlation between students' reading comprehension skills and their science proficiency [39]. PISA results since 2003 have shown that Indonesian students' performance in reading and science has consistently been below the average calculated for Organization for Economic Cooperation and Development (OECD) countries [40–44]. This means that implementing complex SSIs in Indonesian science education may be more difficult than in other countries.

Some participants also addressed personal limitations in their own knowledge, experience, and expertise when it comes to SSI-based teaching. They felt that they do not have sufficient time and expertise in creating material for innovative instruction, as previously also reported by Fogleman et al. [45]. Another challenge suggested by many of the teachers was the lack of facilities to support SSI-based instruction, including Internet access. The students are not allowed to use a mobile phone during the lesson so that the students cannot access the Internet. Presley et al. or Marks and Eilks [14,33] recommend using authentic media offerings to establish a classroom connection to the real world. They argued that teachers and students can use digital communication technology in order to access many forms of media such as newspaper content, videos, Internet pages, etc. Moreover, students' personal perception of the relevance of science education might be enhanced by the use of authentic media [46]. This is, however, difficult if access to digital media and the Internet in schools is limited.

The teachers in this study also viewed the nature of science content in the curriculum as a challenging factor when trying to implement SSI-based instruction. Most of the teachers felt obliged to concentrate on delivering condensed science content in order to prepare their students for final exams. This is in line with the findings reported by Subiantoro [12]. Moreover, in the teachers' opinion, SSI-approaches require inordinately large quantities of time, both in lesson preparation and in carrying out lesson plans. One of the teachers, who had worked with transgender issues in the topic of human growth, stated that the students were very excited about the controversies regarding the societal aspects of this issue. She, however, also reported that their intense discussions had to be limited in class due to time constraints. Similar perception regarding limited time was also acknowledged by Korean science teachers [23].

Although the teachers perceived SSI-based education positively and saw its potential for character formation, the participants did not exhibit correspondingly high levels of implementation of SSI-based education in their classrooms. It is suggested that teachers must be given more resources and be provided with thorough support in order to overcome any difficulties encountered in implementing SSI-based learning [38,47]. Such support needs to be provided by policy makers, curriculum developers, and science education research so that teachers can overcome any problems they face in implementing SSI-based pedagogies at the classroom level. This should result in developing SSI-based teaching and learning materials and corresponding media. The development could start with advantageous topics such as environmental pollution, food biotechnology, or global warming, which easily lend themselves to SSI-focused efforts.

5. Conclusions

About half of the teachers in the current sample were familiar with SSI-based learning, at least to a certain extent. Regardless of their missing theoretical knowledge, however, some of the other teachers had implemented SSIs to varying degrees in their classrooms, although not on a regular basis. Since many of them perceived SSI-based teaching and learning as a promising field, the situation might be bettered if any associated barriers could be overcome. The main barriers suggested by the participants concerned limits in students' skills, a lack of teachers' knowledge and expertise, the prevalent curriculum, lack of facilities, and time constraints. The best thing science education research and development can offer to overcome these obstacles is an investment in designing SSI-focused science learning sources and a commitment to continuous professional development concerning their usage.

6. Limitations

This study has several limitations. It only focuses on the Indonesian context and is merely a general survey. It nevertheless allows some practical insights into the practices and views of Indonesian teachers when it comes to implementing SSI-based instruction. The current study suggests that further research and action is needed to develop and evaluate practices of implementing SSIs in Indonesian science education. It also indicates that researchers need to explore exactly how teachers can develop expertise and experience with the aid of associated professional development.

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PAPER 2

Indonesian pre-service science teachers' views on socio-scientific issues-based science learning

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Indonesian Pre-Service Science Teachers' Views on Socio-Scientific Issues-Based Science Learning

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Abstract

This study explores the views of Indonesian junior high school pre-service science teachers (PSTs) towards teaching based on socio-scientific issues (SSIs). Questionnaires were analyzed qualitatively and descriptively. The PSTs (N=62) acknowledged that student competencies ranging from personal to socially relevant skills as well as character formation can potentially be developed through SSI-based instruction. The PSTs mentioned several challenges which may hinder implementation of SSI-based instruction. These include the interdisciplinary and controversial nature of SSIs, a lack of familiarity regarding SSIs, the lack of necessary student skills, insufficient teacher expertise, and curriculum constraints. The PSTs viewed SSIs as able to potentially enhance their personal competencies through SSI-based instruction, mostly with regard to pedagogical skills. The relevance of SSI-based instruction was, however, not seen in as positive a light as the participants' views on the need of character building. The PSTs' intentions to later implementing SSI-based instruction ranged from medium to high.

Keywords: science education, curriculum, socio-scientific issues, pre-service science teachers

INTRODUCTION

Ever since the 1960s, the goals of school science education in many countries has shifted from a primary focus on preparing the next generation for science-related careers to achieving scientific literacy for all (Eilks, Rauch, Ralle, & Hofstein, 2013). Scientific literacy can be defined as the ability to recognize scientific questions and to utilize knowledge and skills from science. This includes making informed decisions regarding any science and technology related issues or problems in modern life and society. Approaches to achieving scientific literacy found in the literature suggest reorienting science learning along the lines of contexts relevant to everyday life (Childs, Hayes, & O'Dwyer, 2015) or using societal relevant questions (Hofstein, Eilks, & Bybee, 2011; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). Socially-oriented science education focuses on a broader skill set which reaches beyond the learning of science. Some have suggested that it be organized using socio-scientific issues (SSIs). SSIs are science-related questions that are relevant to life in society and are multifaceted, controversial and open-ended in nature (Sadler, 2011a; Zeidler, 2015).

Knowledge of how to implement SSI-based instruction in Indonesia is limited. It seems that SSI-based science education is rarely implemented in Indonesia (Nida, Rahayu, & Eilks, 2020; Subiantoro, 2017). This study focused on the views of Indonesian pre-service science teachers (PSTs) in junior high school with regard to SSI-based teaching. It explored competencies suggested by the PSTs which should be enhanced through SSI-based education. The study inquired into PSTs' views on the connection of SSI-based pedagogies and student character building. It also asked about the suggested relevance of SSI-based pedagogies for junior high school students. The PSTs were required to suggest potential topics which might be good for carrying out SSI-based instruction in science education. The participants also listed potential challenges in implementing SSI-based learning and discussed their personal willingness to try out the corresponding lessons in the future.

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Contribution to the literature

- The findings of this research contribute to understanding potentials and challenges in implementing SSI-based science education as a new pedagogical approach in Indonesia.
- The study explores the connection of SSI-based science education and students' character formation and inquired into the relevance of SSI-based education for secondary school students.
- The study suggests to thoroughly implement SSI-based education in pre-service science teacher education and continuous professional development in Indonesia.

FRAMEWORK

One of the frameworks for SSI-based science education has been proposed by Sadler (2011b), which was further developed by Presley et al (2013). According to the framework by Sadler (2011b), SSI-based instruction consists of two core aspects, namely: *Design Element* and *Learner Experience*. Presley et al (2013) added *Teacher Attributes* as another core aspect. The Design Element consist of four features: 1) Instruction is built around a compelling issue; 2) the issue is presented first; 3) scaffolding for higher-order practices is provided (e.g. argumentation, reasoning, and decision making); and 4) culminating experience is provided, which could be done through multiple pedagogies, such as role play, debate, service learning, etc. This is in line with another SSI-framework called socio-critical problem oriented approach, developed by Eilks, Marks and others (e.g. Eilks, 2002; Marks, Bertram, & Eilks, 2008; Marks & Eilks, 2009, 2010). Under this framework, teaching has to be started with a societally-relevant, controversial, current, and authentic issue from the society which allows the learning of science content, while at the same time it engages students into group discussions and decision making processes. According to this approach, a fruitful socio-scientific issue must meet some specific criteria. The issue is authentic and relevant, since it is controversially discussed in the media with different points of view, such as newspaper, TV news, podcast, advertisement, etc. It should allow for open debate in the classroom in which arguments from science and technology may play a role. It is suggested that SSI-based science education starts with authentic media leading via science learning into decision making exercises.

Science teaching with the help of SSIs has been suggested as a way to potentially increase student interest and participation in science learning (Morris, 2014). In traditional science education, student interest has often been described as lackluster for many reasons. These include the beliefs that science content is difficult (Turner, Ireson, & Twidle, 2010) or that science is irrelevant (Sjøberg & Schreiner, 2005). The literature suggests that students can be motivated to learn science if they find the contexts provided for science learning to be personally relevant (Bybee & McCrae, 2011). However, what students perceive as relevant is not always in line with what teachers think is important (De Jong & Talanquer, 2015). Therefore, science teaching needs to be made relevant for all students by considering their personal interests and needs for the present and the future (Stuckey et al., 2013). Science learning should start from contexts connected to students' lives in society, their prior experiences, as well as their interests (Childs et al., 2015). SSIs represent a special form of context, because they are authentic, relevant and controversial in nature (Stolz, Witteck, Marks, & Eilks, 2013). SSI-based education is not merely another form of context-based science education, it aims centrally at promoting general educational skills which enable students to actively participate in a democratic society (Eilks et al., 2013, Eilks, 2015). SSIs can be used as a special form of context which motivates students to learn science. They can also serve as a starting point to practice skills which learners require to become scientifically literate individuals in a contemporary society (Sadler, 2011a, 2011b).

Furthermore, character formation and values education have been acknowledged to be a part of scientific literacy for the 21st century (Choi, Lee, Shin Kim, & Krajcik, 2011; Sjöström & Eilks, 2018). Character formation and values are assumed to be driving forces that serve as general points of reference for individuals to make responsible decisions regarding local or global SSIs (Choi et al., 2011; Lee, Chang, Choi, Kim, & Zeidler, 2012). SSIs have been suggested as a vehicle which can promote character formation and values education for global citizenship (Lee et al., 2013). Science education should be therefore linked to character-building education (Berkowitz & Simmons, 2003). It should also be integrated into citizenship education in order to promote the necessary skills for being responsible citizens (Sperling & Bencze, 2010). Teaching using SSIs is seen as having the potential to enhance students' moral sensitivity and contribute to their moral development (Fowler, Zeidler, & Sadler, 2009). It also provides students with chances to practice education for responsible citizenry (Zeidler & Nichols, 2009). In the case of Indonesia, the government has explicitly emphasized the need for moral character development through formal and informal education as stated in the Peraturan Presiden Republik Indonesia Nomor 87 Tahun 2017 (2017). In this framework, science education plays an important role in emphasizing character building as a part of formal education, for example

Table 1. Description of the questionnaire

Item	Question	Focus	Type
1	Challenges	Potential challenges to implement SSI-based education	Open-ended
2 & 3	Promotion of competencies/ skills	Learners' competencies or skills potentially enhanced through SSI-based education	Open-ended
		Teachers' competencies or skills potentially enhanced through SSI-based education	Open-ended
4 & 5	Character formation	Contribution of SSI-based education to learners' character formation	Likert type
		Reasons for the answer on item no.4	Open-ended
6 & 7	Relevance	Relevance of SSI-based education for learners	Likert type
		Reasons for the PSTs' answer on item no.6	Open-ended
8	Potential topics for SSI-based education	Potential topics to implement SSI-based learning from 33 main topics of the Indonesian junior secondary school curriculum	Multiple-select
9	Intention	Intention to implement SSI education when teaching in a school internship	Likert type

through the enactment of an SSI-based pedagogy to support character formation.

Research on SSI-based pedagogies is an emerging topic, but its implementation in Indonesia remains limited (Subiantoro, 2017; Nida et al., 2020). Studies exploring pre- and in-service science teachers' views of SSI-based learning have been published, but most are from outside Indonesia. Lee, Abd-El-Khalick, and Choi (2006) conducted a Korean study examining secondary school teachers' views on introducing SSI into the science curriculum. The results indicated that the teachers saw a need to address SSIs. However, only a small number of the participants actively used such issues in their own classrooms and the application was sporadic at best. The participants also mentioned several obstacles to teaching with SSIs such as a lack of time and the inaccessibility of relevant materials. Similar results were reported for Turkey by Kara (2012), who explored the perception of SSIs in the curriculum among biology teacher trainees.

In Indonesia, the number of studies examining science teachers' views regarding SSI-based science education is very limited. Subiantoro (2017) explored Indonesian senior high school biology teachers' views on SSI-based education. The findings reveal that before participating in the study, teachers had limited knowledge and experience regarding SSI-based learning. After being trained, their knowledge on SSI-based instruction had expanded and their views regarding the benefits and challenges of such an approach had changed. Similar results were recently found for Indonesian junior high school science teachers (Nida et al., 2020). This latest study covered teachers' views on SSI-based learning. Despite several challenges to implementation mentioned by the teachers, the participants expressed positive views on SSI-based instruction. They believed that SSI could contribute to students' skill set development and aid in character formation. Most of the teachers were also interested in implementing SSIs in their own classes and considered some potential science topics to incorporate SSI-based education.

Teachers are the key to curriculum change (Anderson & Helms, 2001). This holds true for in-service teachers. It is even truer for prospective teachers, since future teachers play a central role in enacting and spreading instructional innovation which they learn about in their teacher education programs (Davis, Petish, & Smithey, 2006). Inspired by the study previously done by Nida et al. (2020), we conducted a similar research focusing the pre-service junior high school teachers. The current paper details a study of PSTs in Indonesia with regard to the use of SSIs in science education. We examined the participants' views with respect to the potential benefits and challenges of SSI-based instruction to enhance skills and character formation. We also inquired into the relevance of learning about SSIs and investigated suggested topics for implementing SSI-based education, as well as the student teachers' intension to implement SSI-based instruction later when they become a science teacher.

METHOD AND SAMPLE

The study is based in a questionnaire adapted from Nida et al. (2020), with one multiple choice, three Likert and five open-ended items. At the beginning of the questionnaire, a definition and an example of SSI-based education is presented. This provides all the respondents with the same definition of what SSI-based education means. As a part of the questionnaire, the PSTs were asked about their knowledge of and familiarity with SSI-based education and any sources of information that they had used so far. An overview of the questionnaire with the different questions and foci (challenges, promotion of competencies/skills, character formation, relevance, potential topics, and intention of implementation) is provided in Table 1.

A total of 62 PSTs from Indonesia took part in the study. All of them were in the seventh semester of their university science teacher education program at a public university in East Java. There were 57 (91.9%) of the participants who were female and 5 (8.1%) who were male. This is not an unusual distribution in science teacher programs in Indonesia. All participants took part in the study voluntarily.

The Likert and multiple-choice items were subjected to descriptive statistics. The Likert items were scored on a scale from 0-4 (0 not at all; 4 to a very great extent). Mean values were calculated, with higher values

Table 2. PSTs' views on the challenge of implementing SSI-based education (% = PSTs mentioning)

No	Category	Description	Examples	%
1	Multidisciplinary/ multi-perspective nature	Any response related to the multidisciplinary, wider range of needed knowledge, up-to-date knowledge, or the ability to assess things from multiple perspectives	A wide range of knowledge is needed to implement this approach; this approach requires interdisciplinary knowledge; it is difficult to assess things from multiple perspectives.	38.7
2	Controversial nature	Any response related to the controversial nature of SSIs	Sometimes the controversial nature of a socio-scientific issue becomes a challenge that might impede the enactment of this learning approach; my concern is about the appropriateness of the controversial issue presented for the students; the controversies within SSIs might lead to differing positions; the issues (SSIs) might cause the discussion to go in multiple directions; some issues are very sensitive topics within society.	30.7
3	Unfamiliarity and missing expertise	Any response related to the teachers' low level of knowledge, skills and expertise in implementing SSI-based education	Teachers have limited knowledge and experience in implementing SSI-based instruction; teachers often focus only on delivering science content; I question teachers' ability to reach the science teaching goals by using SSIs.	27.4
4	Students	Any response related to students, such as missing competencies and low levels of motivation or awareness	Students have low levels of awareness regarding socio-scientific issues; students have low reading ability; students' low understanding of the scientific concepts which are very important for them to be able to discuss the issue; some students are not very familiar with the controversial issues which are currently found in society.	25.8
5	Curriculum	Any response related to the difficulty of integrating SSIs with the content in the curriculum	Not all science content can be taught using SSI-based instruction; sometimes it is difficult to integrate the SSIs with the content provided in the curriculum.	24.2
6.	Support	Any response related to support for SSI-based instruction	There are not enough learning materials available based on the socio-scientific issue.	3.2

indicating more positive views. The open-ended responses were qualitatively analyzed following Mayring (2014). The items were coded and categories developed. Initial categories were then developed cyclically based on the most frequent answers, checked against the data, and modified along a first analysis. The final coding was carried out independently by two researchers with an inter-rater reliability of 92.5%.

FINDINGS

Experiences

The majority of the participants in the study stated that they were not familiar with SSI-based science education (72.6%). Only 17 out of 62 respondents reported having read/heard/known about the topic. Most of these people had been introduced to SSI-based education through either journal articles or colleagues. None of them had received knowledge on SSI-based education during their teacher education courses.

Challenges in Implementing SSI-based Learning

Six categories of challenges in implementing SSI-based instruction could be identified (Table 2). The two most common challenges were related to the multidisciplinary character and controversial nature of SSIs. The other problems mentioned included teachers' lack of familiarity with the topic, too little expertise in implementing SSI-based education, an estimated lack of student competencies, and challenges related to matching up or integrating SSIs into the science curriculum.

Competencies

The PSTs suggested several competencies that might be developed through SSI-based education, not only for the learners but also for the teachers. Student competencies mentioned by at least 10% of the PSTs were sorted into categories. These included problem solving, critical thinking, higher-order thinking, communication, character, interconnecting science-technology-society-environment, collaboration and curiosity (see Table 3). Further competencies mentioned by less than 10 % of the PSTs included creativity, scientific reasoning, scientific literacy, scientific inquiry, content knowledge, the nature of science, and decision-making skills.

Aside from considering learner competencies that can be enhanced by SSIs, the PSTs also mentioned competencies that can potentially be developed among teachers. The most commonly mentioned ones fell into eight categories. These include designing innovative contextual learning, attaining wider knowledge, increasing teaching skills/classroom organization, gaining multidisciplinary knowledge, adding teaching skills, promoting creativity, maintaining neutrality,

Table 3. PSTs' views on competencies which learners can potentially develop (% = PSTs mentioning)

No	Category	Description	Examples	%
1.	Problem solving	Any response related to problem solving skills	The students learn to solve a problem scientifically and also consider societal needs.	43.5
2.	Critical thinking	Any response about reflexive and critical thinking	Students can enhance their critical thinking skills; the students can reflect upon information regarding the SSI so that they can make an informed choice or decision.	41.9
3.	Higher order thinking skills	Any response related to higher order thinking skills based on Bloom's taxonomy	Higher order thinking skills; the ability to analyze the problem within society.	27.4
4.	Communication	Any response about communication skills	The ability to convey ideas, criticize, answers, and ask questions; the ability to present data using tables, charts, etc.; the ability to ask/answer questions, or to get involved in a discussion.	25.8
5.	Character	Any response related to character formation	The ability to show positive attitudes regarding the SSI such as open-mindedness, appreciating different opinions, enhancing positive attitudes and building character.	17.7
6.	Multidisciplinary nature	Any response related to interconnection science-technology-society-environment or related to multidisciplinary nature of SSIs.	Connecting what the students learn at school with society; implementing scientific knowledge in society.	14.5
7.	Collaboration	Any response related to collaboration either within the community or society at large	The students know how to work together with society to solve a problem using a win-win solution to the controversy.	11.3
8.	Curiosity	Any response related to curiosity	Increase learners' curiosity and interest in learning science.	11.3

Table 4. PSTs' views on competencies teachers potentially develop (% = PSTs mentioning)

No	Category	Description	Examples	%
1.	Designing innovative contextualized learning	Any response related to the ability in context-based learning by utilizing SSIs and integrating SSIs with the curriculum	Choosing suitable issues for science topics; the ability to analyze societal problems and integrate them with learning activity by providing real life examples/contexts; the ability to integrate science/technology and society and make it a learning activity; the ability to enhance students awareness about societal issues; the ability to design science learning based on real-life problems.	46.8
2.	Wider knowledge	Any response about enhancing knowledge	Teachers can gain a wider range of knowledge; they have up-to-date information.	21.0
3.	Teaching skills/classroom organization	Any response related to abilities in teaching or organizing the classroom	The ability to organize discussion and fruitful debate; the ability to help students think of and propose ideas to solve the problems faced within society; skills in directing the discussion so that students can take a position regarding the issue; the ability to utilize the issue in the discussion so that the students can analyze the problems; the ability to direct students in thinking critically regarding the issue; the ability to simplify the complexity of the SSI so that the students can follow the instructions easily; the ability to motivate students in discussions; the ability to choose suitable teaching models for SSI-based learning.	22.6
4.	Multidisciplinary knowledge	Any response about inter- and multidisciplinary knowledge	The ability to relate/connect science with other disciplines.	16.1
5.	Creativity	Any response about creativity	Creativity in presenting the issue to be an interesting topic for the students to discuss	9.7
6.	Neutrality	Any response about the teachers' neutral position	The ability to be neutral to the different positions, so that the teachers' personal beliefs do not interfere with students to finding a position; the ability to be open and facilitate students presenting different positions in dealing with the SSI	6.5
7.	Utilizing learning resources	Any response related to providing learning resources for students	The teachers' ability to provide students with access to learning resources which support this approach; providing students with suitable media for learning.	4.8
8.	ICT	Any response about the ability in utilizing ICT	The ability to develop and utilize ICT-based media for teaching; the ability to access information through ICT-based media.	4.8

utilizing learning sources, and bettering information and communication technology (ICT) skills (see Table 4).

Table 5. PSTs views on character formation and relevance

Aspect	Number of response	Score* 0	1	2	3	4	Sum	Mean value	Standard deviation
Character	62	0	0	9	18	35	212	3.42	0.74
Relevance	62	0	1	17	36	8	175	2.82	0.67

*0: not at all, 1: to a small extent, 2: to some extent, 3: to a great extent, 4: to a very great extent

Table 6. PSTs' justifications concerning character formation (% = PSTs mentioning)

No	Category	Description	Examples	%
1.	Awareness	Any response related to awareness, either social or environmental	Students can become more aware of the problems occurring in society; students become aware of their environment; students take more care of others.	22.6
2.	Open mindedness	Any response related to open-mindedness and respecting others' views	Students become more open to different opinions; conveying ideas critically in a polite manner.	22.6
3.	Real world examples/contexts to strengthen character formation	Any response about SSIs being real life contexts for addressing societal problem as well as strengthening character	Through SSIs, we can connect science with real life phenomena in society that can be used to strengthen character formation.	21.0
4.	Responsibility in making decision	Any response related character in decision making and to take a position	Students would be wise to face/react/take action/decision regarding societal problems; students think twice before they choose an action; when SSIs are implemented, students can learn science through them, as well as learning to take a position in their society; students can make responsible decisions; students can think scientifically when they need to face different arguments	17.7
5.	Problem solving	Any response related to problem solving	Students can be provoked to find solutions about a societal problem; students can identify problems in their society and try to find a solution to those problems	14.5
6.	Appreciation of values and ethics	Any response related to values and ethics	Students can appreciate values which come from their culture.	11.3

*0: not at all, 1: to a small extent, 2: to some extent, 3: to a great extent, 4: to a very great extent

Character Formation and Relevance

The PSTs' views regarding SSI-based education as a contributor to character growth and its relevance for the students were scored from 0 to 4. Zero was rated as "not at all". A value of four meant "to a very great extent". All of the PSTs perceived SSI-based education positively. Most of them thought that SSI-based education can contribute to building learners' character to very great extent. The mean value for this item was 3.42 (Table 5). Most of the PSTs saw SSI-based learning as being relevant to the students. However, SSI relevance for students did not score as positively as character building did. The mean value for relevance was 2.82 (Table 5). Table 5 also shows the comparison between the PSTs' single answers on character formation and how relevant SSI-based education is.

The reasons for PSTs' positive views on character formation fall into six categories (Table 6). These categories represent aspects of character that can potentially be enhanced or expanded. These include student awareness, open-mindedness, real world examples/contexts to strengthen character formation, responsibility in decision-making or taking a position, problem solving, and appreciation of values and ethics.

The PSTs' responses to the relevance of SSI-based learning for students were classified into six categories (Table 7). The participants who had positive views indicated that SSI is relevant for students because it is often connected to daily life. They viewed SSI as interrelating science / technology and environment / society. SSI can possibly enhance the multidimensionality of skills / competencies. Such topics are also controversial in nature and are currently being debated in society at large. The respondents who saw SSI-based education as less relevant suggested the controversial nature of SSIs could also be a negative aspect. One reason for this is that pros and cons can arise which make a topic difficult to handle. Another reason mentioned was that this approach cannot be applied to all topics in the science curriculum.

PSTs Intention to Implement SSI-based Education

The PSTs' intentions of implementing SSI-based education was also scored on a scale from zero to four. Intention was defined as a participant's willingness to implement SSI-based education should they be asked later in the teaching internship program. The mean value of the PSTs' intentions was generally positive with a value of 2.76 (Table 8). This was less positive than the mean values found for the contribution of SSI-based

Table 7. PSTs' answers concerning relevance (% = PSTs mentioning)

No	Category	Description	Examples	%
1	Real life contexts/ issues / problems	Any response about SSIs being real life contexts or problems faced by society that can be observed by the students, interest them, and can be used to provoke discussion	SSI-based learning is about the problems currently faced by society; it is not like the textbook; this approach is based on exploration of their environment by the students; students are directed to think about the issue so that they can be more actively involved in the discussion; the issue is very close to students' lives and that makes them more interested.	43.5
2	Interrelatedness of the issue with science/ technology/ environment/ society	Any response about the interrelatedness of the SSI with science/technology and environment/society that enhances students' knowledge	Students might connect the scientific and environmental issue; the issue can be used to discuss other aspects such as economics, culture, science, etc. under one topic and is suitable for integrated science learning; students can analyze the issue through multiple perspectives that the students provide and that brings wider knowledge.	30.6
3	Enhances multiple dimensions of competencies	Any response related to SSI's role in enhancing multiple dimension of students competencies, either thinking skills, problem solving skills, critical thinking skills, cognitive, affective, psychomotor, etc.	Students might enhance their cognitive, affective, psychomotor skills; students might enhance their higher order thinking skills, which are needed for their professional work in the future; this approach can be used to strengthen character formation; students can increase their critical thinking skills; students learn to solve problems scientifically.	16.1
4	Controversial nature	Any response related to the controversial nature of SSIs	It is the controversial nature that I think will not work (for the students); there will be pros and cons and it is difficult to get a win-win solution; the controversial nature can make students more aware of the issues and make them try to analyze and discuss it.	8.1
5	Currently being under debate	Any response related to SSIs as being current topics of discussion in society	The issue is currently being discussed by society; the issue is not new for the students.	6.5
6	Not all content can be taught using SSI-based education	Any response related to unsuitability for the whole curriculum	Not all material can be adapted to this approach; not all topics are suitable for SSI-based learning.	4.8

Table 8. PSTs' willingness to implement SSI-based education

Aspect	N	Score*					Sum	Mean value	Standard deviation
		0	1	2	3	4			
Intention	62	0	0	28	21	13	171	2.76	0.78

*0: not at all, 1: to a small extent, 2: to some extent, 3: to a great extent, 4: to a very great extent

learning towards character formation (3.42) and SSI relevance (2.82) (see Table 5). The PSTs' willingness to implement SSI was less positive than the other categories. However, we should note that none of the PSTs replied negatively to implementing SSI-based education. The majority said that they would implement SSIs to some or to a great extent. Some PSTs even said that they would do so to a very great extent.

Potential Topics to Incorporate SSIs

The participants named several topics which they considered to be helpful for incorporating SSIs into teaching practice (Table 9). There are ten topics in the lower secondary school science curriculum in Indonesia which were suggested by at least one-third of the PSTs. The topics are mostly related to environment or technology.

Table 9. Potential science topics for SSI-based instruction

No	Topic	%
1.	Environmental pollution	82.3
2.	Global warming	80.6
3.	Food biotechnology	71.0
4.	Green technology	66.1
5.	Addictive and additive	62.9
6.	Civilization and environment	48.4
7.	Interaction of living things and environment	46.8
8.	Electricity and electrical technology in the society	40.3
9.	Heredity	37.1
10.	Energy in life systems	33.9

DISCUSSION AND CONCLUSION

SSI-based education was relatively unknown among the Indonesian PSTs in this sample. They had limited knowledge and experience about utilizing SSIs to teach science. All of the participants had had a course on science-technology-society. However, most of them had no experience prior to this study with approaches based in authentic and controversial SSIs as a basis for science education. Theoretical justifications and conceptual ideas on the inclusion of SSIs in science based education are needed in science teacher education for later implementation (Sadler, 2011a). This also seems to be the case for Indonesia. In a study by Nida et al. (2020), practicing teachers described students' lack of competency in dealing with SSIs as the largest expected challenge in implementing SSI-based education. Among the PSTs, the multidisciplinary and controversial nature of SSIs was listed as the largest challenge to teaching, since the units incorporate a variety of societal factors ranging from politics to economics to ethics (Sadler, 2011a). This was, however, also mentioned by many in-service teachers in Indonesia in the study by Nida et al. (2020). This was also paralleled in a Thailand study published by Pitiporntapin, Yutakom and Sadler (2016), in which PSTs tended to prefer uncontroversial issues for students to learn science. The PSTs in this study said that the controversial nature of SSI is not familiar to students. This avoidance of controversial issues might not just be due to teachers' views of their students. Teachers often do not address controversial science-related issues because they themselves do not have a clear position (Lee et al., 2006).

The findings above suggest that teacher education needs to more thoroughly incorporate not only the learning *of* science, but also *about* science and its inter-relatedness to other disciplines. Teacher trainees also need to learn about scenarios and pedagogies for effectively dealing with controversies in education, for example structuring discussions or role-playing. Both learning about multidisciplinary SSIs and covering how to deal with controversies are needed, if we intend to lower the barriers for effectively implementing SSI-based education. This will remain a challenging task for teachers, as Owens, Sadler and Zeidler (2017) suggest:

"Introducing students to relevant and contentious issues, helping them contextualize science ideas and practices toward the resolution of the issue, and tasking them with creating effective arguments and evaluating those of their peers is critical for promoting the kind of civil discourse that democracy requires, but it can be a daunting task for teachers" (p. 47-48)

Although the PSTs from this sample listed several challenges in implementing SSI-based education, they also acknowledged that many competencies might be promoted among both students and teachers. The first three competencies mostly acknowledged by the PSTs were problem-solving, critical thinking, and higher-order thinking. These three skills can be generalized into higher-order thinking skills that can be defined in term of transfer (the ability to use the knowledge in a more complex ways), critical thinking (reasonable reflective thinking focused on deciding what to believe or do), and problem-solving skills (the ability to identify and solve problems in life), as suggested by Brookhart (2010). Following Holbrook and Rannikmae (2007), the skills promoted by societally-oriented science education by the PSTs cover both the individual and societal domain. In the individual domain, intellectual skills, such as problem-solving, critical thinking or communication skills are believed to be enhanced by SSI-based learning. In the societal domain, understanding the interlinkage of science-technology-society and collaboration skills might be fostered. A few of the PSTs also acknowledged advantages for the nature of science domain by promoting inquiry or scientific investigation skills, scientific reasoning, or understanding the nature of science. Most of the skills mentioned by the PSTs were also in line with the those acknowledged by the in-service teachers in the previous study by Nida et al. (2020), although with slightly different order.

The PSTs also recognized several competencies that teachers might develop if SSIs are used in teaching. The most frequent responses were related to pedagogical skills such as designing innovative contextual learning, classroom organization and teaching skills, and utilizing various learning resources in teaching. This is also similar with the in-service science teachers' responses about the teachers' skills that are potentially enhanced (Nida et al., 2020). Most of the skills the in-service science teachers mentioned were related to pedagogy. Everyday issues which frequently appear in the news or media, commonly about environment, energy, and resources (e.g. SSIs) have all been suggested as daily life contexts to relate science to students' daily life (Childs et al., 2015). SSIs therefore may affect learner motivation, orientation, topic illustration, and material application as suggested by De Jong (2008). SSIs seen to provide a motivational function for students, because they are strongly related to one's personal and societal life. Teachers also utilize SSIs as contexts for their students to learn science concepts, although it is clear that not all traditional science content can be covered with SSI-based education. The PSTs, however, did acknowledge that SSI-based learning requires them to acquire a wider range of knowledge and skills, such as multidisciplinary knowledge and the ability to develop and utilize ICT-based media for teaching. This has also been suggested by Morris (2014), Evagorou (2011), and Presley et al. (2013). Additionally, better skills at forming networks of students, teachers, experts and other members of societal groups might be needed (Chen, Seow, So, Toh, & Looi, 2010). Less often mentioned, but also necessary, is the development of a stance of neutrality regarding different positions. This ensures that teachers' personal beliefs do not interfere inadequately with the students' positions.

A very important point for the PSTs was the potential role of SSI-based education in influencing students' character formation. This was valued more highly than the relevance of students to learning about SSIs. One reason might be in the explicit focus of character education in the official Indonesian educational policy

(Peraturan Presiden Republik Indonesia Nomor 87 Tahun 2017, 2017). Generally, it has been suggested that SSI-based education could play a role in developing character and imbuing values as global citizens (Lee, et al., 2013), such as in making responsible decisions and taking action on global issues (Lee et al., 2012). SSI-based education was seen to contribute to certain aspects of character formation, such as awareness, open-mindedness, as well as responsibility. These aspects of characters were also the three most acknowledged characters by in-service science teachers (Nida et al., 2020).

Because SSIs are viewed positively in regard to building character and being relevant to learners, they are also desirable to most teachers. The participants in this study tended to want to employ SSI-based education in the future. Whether this will lead to implementation of SSI-based education must be viewed with caution, since it faces many hindering factors. This is especially true for the question of whether or not junior high school students have sufficient skills for dealing with controversial issues. Missing skills were also reported in a study published by Kara (2012) in Turkey, where PSTs were concerned that their students were not mature enough to make judgments regarding SSIs. Ekborg, Ottander, and Silfver (2013) also reported that teachers tend to think that school students are too young and have too little prior knowledge and experience in handling SSIs. One controversial belief among teachers about the level of skills and knowledge necessary for understanding controversial SSIs can be found in a study examining teachers' views regarding teaching climate change in Germany (Feierabend, Jokmin, & Eilks, 2011). All this must be considered, however, to be less a question of students' skills and more an issue of adequate pedagogies and teachers' investment in their pupils' skills development.

This study is somewhat limited by its sample size and its focus on only one group of PSTs from Eastern Java. However, the results may help us to better understand Indonesian PSTs' views regarding the challenges and potential of SSI-based education. The study suggests that SSI-based education needs to be more thoroughly inserted into PSTs teacher pre-service education and continuous professional development. To implement this, the development and dissemination of examples, resources, and support structures are needed to overcome some of the expected difficulties (Mamlok-Naaman, Eilks, Bodner, & Hofstein, 2018). The program needs to provide PSTs with examples of how SSIs can be incorporated into science class using issues relevant to the Indonesian context. Then they can experience the corresponding practices themselves in teaching and during their teacher education seminars. The examples could start with the topics mentioned by PSTs or in-service teachers (Nida et al., 2020) which are believed to have potential, such as environment pollution, global warming, food biotechnology, green technology, etc.

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PAPER 3

A case study on the use of contexts and socio-scientific issues-based science education by pre-service junior high school science teachers in Indonesia during their final year teaching internship

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A Case Study on the Use of Contexts and Socio-Scientific Issues-Based Science Education by Pre-service Junior High School Science Teachers in Indonesia During Their Final Year Teaching Internship

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This paper presents a case study looking at the use of daily life contexts and socio-scientific issues by pre-service science teachers (PSTs) in Indonesia during their final year teaching internship. The study is based on a questionnaire distributed to 42 PSTs at a State University in East-Java after they took part in a teaching internship program. The questionnaire focuses on the contexts the PSTs used in their teaching and how the contexts were used. Additionally, eight of the PSTs who taught a unit on environmental pollution were interviewed to more deeply explore how deeply they referred to real-world contexts in their teaching practice and whether or not they presented the topics as socio-scientific issues (SSIs). Most of the PSTs stated that they had used daily life contexts quite often when teaching. The most frequent contexts the PSTs used were daily life objects and questions related to society and the environment. The contexts were mostly introduced at the beginning of the lesson, before the science content was taught. They suggested that the function of contexts was generally for motivational purposes and for student engagement with science concepts. The contexts were rarely used to provoke societal discussions, even though the PSTs acknowledged that many contexts can be used in the sense of socio-scientific issues and were considered to potentially provoke discussions beyond science.

Keywords: science education, teacher education, socio-scientific issues, pre-service teachers, context-based learning

INTRODUCTION

In the past, school science in many countries, such as in Sweden, England, and Australia, has been characterized as generally being structured around decontextualized content which is often perceived as difficult to learn by many students (Lyons, 2006). Traditional science curricula have been described as being overloaded with content (Gilbert, 2006). Many students find much of the science content to be irrelevant for their lives (Gilbert, 2006; De Jong and Talanquer, 2015) and not in line with their interests (Oscarsson et al., 2009). As a result, interest in learning science has declined over time in many of these countries (Jonathan et al., 2003; Barmby et al., 2008), such as in Western European countries (OECD, 2007). Science education has a great role in enhancing the awareness of and positive attitudes toward science related carriers (Vaino et al., 2015). The perceived irrelevance and difficulty of learning science is believed to be worsened, if teachers do not connect science learning to students' daily lives (Childs et al., 2015). There has been many attempts to address students' lack of interest in learning science through context based science education, such as the Science-Technology-Society movement, which highlight societal issues to enhance students' critical thinking skills and social responsibility (Holbrook and Rannikmäe, 2010). It has further been suggested that science teaching needs to be better connected to societally relevant questions (Hofstein et al., 2011) and to be tied to the use of socio-scientific issues (SSIs) in order to make science curricula relevant (Sadler, 2011a; Stuckey et al., 2013). A recent study of Indonesian educational context found that to date most experienced junior high school teachers rarely implement SSIs in their teaching (Nida et al., 2020). This is why the current study explored whether pre-service Indonesian science teachers choose to use SSIs when asked to gather first-hand teaching experience during the final year of their teaching internship program. This study investigates the use of contexts and socio-scientific issues-based science education among pre-service science teachers (PSTs) attending a State University in East-Java.

THEORETICAL FRAMEWORK

Constructivist learning theory suggests that when contexts are integrated with science learning the outcomes are more meaningful to students (Greeno, 1998). Childs et al. (2015) have suggest numerous ideas for merging everyday life contexts with school science curricula, including a focus on everyday life objects, everyday materials, everyday activities, everyday issues, and other areas. All of these contexts can serve different functions in science learning. They can be used to open lessons, frame a whole lesson plan, or illustrate science content by highlighting its function and applications in everyday life, technology, their environment, and society (Gilbert, 2006; Eilks et al., 2013b).

Contexts may be used in science education in various ways. Contexts can be used before or after science content learning, or even both (De Jong, 2008). The more traditional approach is to start a lesson from the subject matter for later application to daily life questions. More recently, it has been suggested starting with students' daily lives in order to relate context to develop appropriate science understanding (Roberts, 2007; Childs et al., 2015). The theory of situated cognition (Greeno, 1998) has shown that the traditional approach, which introduces real world contexts only after teaching science concepts, may not be the best way to promote student learning (Overton et al., 2009). Nevertheless, many teachers still start with science content and some even finish there (Childs et al., 2015).

There are numerous functions which contexts can take on in science teaching. Context can be used for motivation, orientation, illustration, or the application of science concepts (De Jong, 2008). Meaningful learning should begin with contexts which are related to students' lives, prior experiences, and personal interests. It should also be connected to actively applying the learned knowledge (Eilks et al., 2013b). However, not all contexts have the same characteristics, nor do they possess the same potential for challenging students in the different areas of learning (Stolz et al., 2013). It is also clear that we need to recognize that the contexts selected by teachers are not always perceived as interesting or relevant by students to the same degree (De Jong and Talanquer, 2015).

One special form of context that can challenge students consists of socio-scientific issues (SSIs) (Sadler, 2011a; Zeidler, 2015). SSIs have the following characteristics (Zeidler and Nichols, 2009; Zeidler, 2015): (1) They are controversial. (2) They present ill-structured problems faced by a society, which require not only scientific evidence-based reasoning, but also moral reasoning or ethic concern. (3) They have social ramifications which require students to engage in discussion, dialogue, debate and argumentation. (4) They are associated with character formation. SSIs need to be authentic, relevant, undetermined in a socio-scientific sense, open to debate, and related to science and technology (Stolz et al., 2013). SSIs have previously been suggested as representing suitable real-life contexts in which students can practice and achieve scientific literacy (Hofstein et al., 2011; Zeidler, 2015). This also holds true for a recently suggested critical vision of scientific literacy, which aimed at preparing students for responsible citizenry in their society (Sjöström and Eilks, 2018). SSIs are deemed appropriate for applying scientific knowledge and skills to societal participation. The skills entailed are necessary for a modern life in which humans, society and the environment are all strongly influenced by the ongoing developments in science and technology (Rundgren and Rundgren, 2010). But SSI-based science education is not only a specific form of context-based learning. SSI-based education also provides a framework for promoting general educational skills. Its focus is on preparing students to be actively involved in a democratic society in which all citizens are required to make decisions concerning the application of science and its associated effects (Sjöström and Eilks, 2018).

In previous studies of teachers' perception regarding SSI-based education in Indonesia, both in-service science teachers (ISTs) (Nida et al., 2020) as well as pre-service science teachers (PSTs) (Nida et al., in press) acknowledged the potential of SSI-based education. They saw it as a means to both enhance students' general educational skills and to broaden teachers' competencies. They also viewed it as a way to contribute to character formation among learners. However, the teachers also listed many perceived challenges when it comes to implementing SSI-based pedagogy. These included both a lack of estimated competencies among students and incomplete teacher experience and expertise when carrying out SSI-based science education. Many of the ISTs and PSTs expressed strong interest in implementing SSI-based instruction in their own teaching. There was, however, a quite large number of teachers who were hesitant to incorporate SSIs to a broader extent.

This paper explores Indonesian PSTs' experiences when it comes to utilizing contexts in their teaching practices. The study looks at their time in teaching internships in junior secondary schools as a part of their bachelor degree program in science education. The focus is on the way the PSTs used contexts in their teaching. Other aspects explored include how the PSTs included contexts in science education and whether or not they incorporated contexts in the sense of SSI-based education.

The research question in this study is: What types of daily contexts do PSTs use when they conducted their teaching internship and how are the contexts presented? Furthermore: How do PSTs use contexts in science education and whether or not do they incorporate contexts in the means of SSI-based education?

SAMPLE AND METHOD

Sample

The sample in this study was comprised of 42 pre-service junior secondary science teachers taking part in a 4-year science education program at a State University in East-Java, Indonesia. The student teachers were in their final year and had had teaching internships in schools during the 2 months prior to this study. The sample consists of 37 female (88.1%) and 5 male (11.9%) student teachers. This is a normal distribution for junior secondary education programs in Indonesia. Six student teachers (14.3%) carried out their teaching internships in private schools, whereas the other 36 (85.7%) taught in public schools.

During their 4 years of study, student teachers must accrue 146 credits in a total of 66 courses. Most of these courses are related to science (chemistry, biology, and physics) and pedagogy. They include lessons in science teaching strategies, media use in teaching, science-technology-society (STS), student assessment, etc. In their sixth semester, student teachers are introduced to context-based learning in an STS course. However, the course does not explicitly focus on how to operate context-based learning in the sense of SSI-based education. Moreover, the latest curriculum changed STS education into STEM education, which still does not necessarily cover an explicit focus on SSI-based learning or the controversial nature of SSIs in society. By their final semester the student teachers have completed both a teaching internship and an undergraduate thesis. The internship require the PSTs to develop their lessons under the supervision of both a mentoring teacher and a teacher educator from the university. The supervisors decide whether the lesson plans are feasible or not with regard to implementing the curriculum. Educators and teachers usually agree on the lesson plan, as long as the targeted science concepts can be delivered within the specified time slot.

All of the PSTs taught in junior secondary schools in grades seven and eight. The teaching internship for pre-service junior secondary teachers usually occurs in these grades, since grade nine focuses on the pupils' final examinations. There is a total of 12 potential science topics to be taught during the second semester of grades seven and eight. On average, each topic is taught in six lessons of roughly 90–135 min. duration. The topic of environmental pollution, for example, receives a maximum of seven lessons. This includes five lessons for teaching and learning, one for the test, and one meeting for remedial teaching (if necessary). Each pre-service teacher had taught at least one of the topics. The unit was based on the time slot in which the student teachers were scheduled to teach during their internship. The topics environmental pollution, global warming, and earth structure were the most frequent units taught by the pre-service science teachers (**Table 1**).

TABLE 1 | The topics taught by the pre-service science teacher.

No	Topics	Grade	Number of PST taught the topic	(%)
1.	Environmental pollution	7	18	43.9
2.	Global warming	7	17	41.5
3.	Earth structure	7	16	39.0
4.	Excretory system	8	9	22.0
5.	Vibration, waves, sound in daily life	8	7	17.1
6.	Respiratory system	8	5	12.2
7.	Light and optics	8	5	12.2
8.	Pressure	8	4	9.8
9.	Human interaction and environment	7	4	9.8
10.	Human organization system	7	3	7.3
11.	Solar system	7	2	4.9
12.	Energy in life systems	7	1	2.4

Instruments

The research consisted of a questionnaire and interviews. The questions in the questionnaire assessed how often the PSTs used daily life contexts during their internship, the type of context that they used, and the order of context and content learning in their classes (**Table 2**). The first question identified how often the PSTs integrated contexts in their teaching. The second question assessed the types of contexts they used with reference to Childs et al. (2015). The last question was on the order of using contexts, either before or after content learning, or both (De Jong, 2008).

The questionnaire study was followed by interviews of eight volunteer PSTs, who had taught the topic of environmental pollution. According to the PST answers, this was the most frequently taught topic. In addition, environmental pollution is a topic that easily can be carried out using an SSI-based education approach. The interviews focused on how the PSTs employed contexts in science teaching, whether or not the PSTs used contexts in the sense of SSI-based education, and how the PSTs integrated contexts as SSIs in their teaching. The interview guide is given in **Table 3**.

Data Analysis

The answers in the questionnaire were descriptively analyzed and percentage distributions were calculated for them. The interview responses were transcribed and analyzed following the tenets of qualitative content analysis according to Mayring (2014).

TABLE 2 | Description of the questions in the questionnaire.

No	Questions	Question type
1.	How often do you usually use daily life context when teaching science? ☐ Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always	Likert
2.	What type of context do you use when you are teaching? (More than one answer is applicable) ☐ Daily objects, either living or non-living objects, such as a laptop, smart phone, vehicle, plant, animal, planet, etc. ☐ Materials/products used in daily life, such as medicines, cosmetics, water, detergents, soaps, oil, insecticides, etc. ☐ Daily activities such as cooking, exercising, washing, etc. ☐ Real life issues related to society and environment on the local/national/global level ☐ Other contexts, such as those related to culture, ethics, economics, etc.	Multiple choice
3.	How do you usually use the contexts mentioned in question #2? ☐ Contexts are introduced at the beginning, before science concepts are taught ☐ Contexts are presented after teaching the science concepts ☐ Contexts are presented before and after teaching science concepts	Multiple choice

TABLE 3 | Questions in the interview; leading question and potential impulses.

No	Questions
1.	This interview wants to know how you utilized contexts when teaching about environmental pollution. a. Which contexts did you use when you taught the topic of environmental pollution? b. How did you operate the contexts? (Was the context chosen to motivate students' learning? Was the context suggested as an orientation for learning?; Was the context used for the illustration of concepts previously learned? Was the context used for applying science concepts?) c. Do you think your use of the contexts fulfilled the characteristics of SSI? Namely: (1) Being presented as controversial and ill-structured problems that need scientific, evidence-based reasoning to make informed decisions; (2) Having societal ramifications of scientific topics that require students to get involved in dialogue, discussion, debate, and argumentation; (3) Tending to have implicit and explicit moral aspects and requiring moral reasoning to some degree; and (4) being associated with formation of virtue/character as a long-range pedagogical goal. d. Did you present any controversy on a context in your teaching?
2.	How did you use contexts in your teaching practice? Did you use it: - As a motivation to teach science concepts behind the context - As orientation for students to learn the science concepts behind the content - To show the inter- relatedness of science, technology, society and environment - To provoke discussion about the context from multiple aspects, not only from science, but also by considering ethical, moral, cultural, legal, or economic aspects - To provoke students to critically analyze the risks and benefits of different positions between the pro and cons - To direct the students to scientific reasoning - To provoke students making argumentation regarding the context - To let students make decisions and take positions - To ask students to propose win-win solutions by considering scientific aspects, as well as ethical concerns

The interview transcripts were coded by the first and second author. For the questions about what kinds of contexts the PSTs present to teach environmental pollution, categories were developed inductively from the interviews. For the questions about how the context was functioned, the category formation was based on De Jong (2008), that the function of context is either as motivation, orientation, illustration, or application. For the questions about how the PSTs use contexts in the class, the response was categorized into whether or not the teaching practice was conducted in means of SSI-based education according to Sadler (2011b). The initial agreement between the two coders was 91%. In those cases of disagreement inter-subjective agreement was reached by a joint re-coding until consensus was reached.

FINDING AND DISCUSSION

Most of the pre-service science teachers stated that they had used daily life contexts quite often in their teaching (46.4%). Another 25.0% described themselves as always using daily life contexts when they teach. The remaining 28.6% said that they sometimes use it. The contexts used in science teaching fall into all the five categories suggested by Childs et al. (2015). The most often used type of contexts the PST used (about 75%) were daily life objects, either living or non-living objects, such as plants, animals, vehicles, etc. (see **Table 4**), followed by real-life issues related to society and environment (more than 50%). All the other three types of contexts were each named by about 30–40% of the participants.

TABLE 4 | Type of context used by the PSTs in their teaching practice.

No.	Context	Number of response	(%)
1.	Daily objects, either living or non-living objects, such as plants, animals, planets, vehicles, etc.	31	73.8
2.	Real life issues related to society and environment on the local/national/global levels	23	54.8
3.	Daily activities such as cooking, exercising, washing, etc.	18	42.9
4.	Other contexts, such as those related to culture, ethics, economics, etc.	16	38.1
5.	Materials/products used in daily life, such as medicals, cosmetics, water, detergents, soaps, oil, insecticides, etc.	14	33.3

The contexts were used in all three potential orders (**Table 5**). Most of the PSTs (50.0%) used contexts at the beginning of the lesson, before addressing the science concepts. Only 9.5%

TABLE 5 | The order of using context in teaching.

No.	How the context is used	Number of response	(%)
1.	Context is introduced at the beginning of the lesson before teaching science concepts	21	50.0
2.	Context is presented after teaching the science concept	4	9.5
3.	Context is presented before and after teaching science concepts	17	40.5

of the PSTs provided contexts after the science concepts were approached. There were 40.5% of the PSTs who utilized contexts before and after teaching the science concepts.

In the interviews, there were a number of contexts named by the PSTs for teaching the topic of environmental pollution. Among them were pollution problems in Indonesian rivers, a cigarette company contributing to air pollution and health problems at the same time, old air conditioners and refrigerators which may release CFCs, and the increasing use of fossil fuels.

The intended function of contexts in the PST teaching practices varied. The most frequent answer given was to motivate students to learn the science concept behind the issue, as shown in the following quote:

> *I presented the issue at the beginning of the lesson using a video showing the polluted river, which is filled with waste. The issue is very close to their lives. They are very highly motivated by the issues arising from their daily lives; they are curious about the science concepts covered in the issue.*

By starting with an interesting context, learning is viewed as more interesting for the students and should therefore enhance their motivation (Overton et al., 2009). Furthermore, the PST used the issue as an engagement or learning orientation to direct the focus to the science concepts:

> *Students tend to like discussing hot-button topics within the society, which are not only those covered in the textbook. I presented the issue to engage the students and to direct them to discuss the science concepts behind the issue. After teaching the intended science concepts, I usually reconnect the concepts with the issue presented at the beginning of the lesson.*

Environmental contexts were mostly used to discuss the science concepts behind them. This included a polluted environment, the sources of pollution, types of pollution, human activities contributing to environmental pollution, the effects of environmental pollution, and ideas for decreasing pollution.

Although acknowledging that the environmental issues used were potentially controversial, none of the PSTs planned to use the controversial points of view to drive the lesson:

> *One of the source of environmental pollution and greenhouse gases is the poultry-based industry. On the one hand, the needs for daily food can be fulfilled. However, there is a concern from an environmental respect. I think that this is a controversial issue. But, I didn't address the controversy in my lesson plan, nor did I use it in the learning process.*

Two PSTs, however, admitted that the controversy around the used issue was addressed by their students, although they had not included it in the scenario of their lesson plan:

> *I actually did not plan to provide the students with the controversies surrounding the cigarette issue. But during the discussion of the sources of pollution, such as human activity including the use of fossil fuels for factories, one student asked the question: "If cigarette factories can negatively affect the environment and cigarettes themselves have negative effects on health, why are people still allowed to consume cigarettes? Why have they not been banned?"*

Another example of controversy which happens in society was addressed in the following quote:

> *[.....] In one of the discussions, the student found herself in a dilemma, because she used a motorcycle to get to school every day [by using a gojek]. She admitted that she contributes to increase in air pollution. But, she didn't have any better choice. We know that we don't have good public transportation.*

In Indonesia, the level of motorcycle and car usage is still increasing. Today, there is a number of online applications such as *gojek*, *gocar*, *uber*, *grab* in which cars/motorcycles can be ordered online for multiple purpose, such as for human transportation, the delivery of goods, ordering food, etc. This information technology-based transportation service is booming in Indonesia and has made life easier on the one hand. One can order these services anytime and anywhere at cheap prices, even when compared to public transportation. Such services allow people to save time and money. On the other hand, these services cause social problems such as tension between conventional traffic and information technology-based transportation service providers. They also increase the use of fossil fuels for transportation, hence contributing to increases in air pollution.

The PSTs seem to find it difficult to use controversies to engaging their students in societal discussions (e.g., to provoke discussion about the issue from multiple angles, not only the scientific ones, to provoke students to do critical analysis on the risk and benefit, to let students do decision making/position taking, or to provoke argumentation). This might be because their students are not believed to be accustomed to discussions of controversial issues. The PSTs themselves may also have little experience in utilizing controversial issues:

> *I used the student's question to open up the discussion. But the students were not used to talking about something controversial like that. Thus, they needed me to initiate questioning, in order to make them think and talk about the issues from different perspectives, not only looking at the negative side, but also the positive side, such*

> *as the economic effects that cigarettes bring for those who work in that sector.*

The PSTs were likely to use non-controversial issues in their teaching, or to completely exclude any controversies behind the chosen contexts. Previous studies (Nida et al., 2020; Nida et al., in press) showed that both ISTs and PSTs feel a lack of personal ability in dealing with controversial issues. This lack in teachers' skills was considered one of the hindering factors when implementing SSI-based learning. The fact that PSTs mostly prefer teaching contexts for student understanding of scientific concepts is not new. Pitiporntapin et al. (2016) in a study in Thailand have also reported that teachers tend to exclude related controversies rather than carrying out SSI-based education. Concerns about the skills and knowledge needed handle controversial issues have also been expressed by Feierabend et al. (2011), who conducted a study on teachers' views regarding teaching climate change in Germany.

Some PSTs indicated an awareness that the environmental context has to integrate science, technology, society, and environment:

> *I used the context to show the students that science/technology are strongly related to society and the environment.*
>
> *Through this issue I also embed technology in water purification and technology in converting plastic waste to fuel by using the plastic waste they produce every day as an example.*

Insecurity in dealing with interdisciplinary knowledge is also one of the hindering factors for implementing SSI-based science education in Indonesia (Nida et al., 2020; Nida et al., in press). SSI-based education, however, should be more than just context-based education to show the relatedness between science, technology, and society. It offers teachers an opportunity to engage students and promote the general skills they need to be actively involved in societal debates, which often require them to make decisions regarding SSIs (Eilks et al., 2013b). This was also acknowledged by the PSTs; they nevertheless decided not choose an SSI-based teaching approach.

From the interviews, we quickly recognized that for the topic of environmental pollution the PSTs rarely incorporated the controversial nature of most of the environmental issues being taught into their lessons. Even if the issue was barely presented as an SSI, the context was mostly used to direct students' learning toward science concepts. It was only used to show its relatedness to society, technology, and the environment, but not to address any controversial nature behind the issue, as has already been reported by Ekborg et al. (2013).

In the strategic plan by the Indonesian Ministry of Education and Culture (Menteri Pendidikan dan Kebudayaan, 2018, 2020), there is a growing agenda about strengthening the curriculum with the emphasis to achieve 21st century skills among students and also fostering education for sustainable development. However, according to the content standards (Menteri Pendidikan dan Kebudayaan, 2016a), as well as core and basic competencies (Menteri Pendidikan dan Kebudayaan, 2016b) for science junior secondary education by Indonesian Ministry of Education and culture, the issue of sustainable development (e.g. through SSI-based learning) is not explicitly articulated.

CONCLUSION

All of the PSTs in this sample used daily life contexts in their teaching practices during their internship program. The contexts preferred most were everyday objects and issues. They tended to be presented at the beginning of the lessons, mainly for motivational purposes and to foster student engagement with science concepts. Any contexts presenting a controversial nature caused the PSTs to generally decide not to provoke discussion of the controversies or to choose techniques specifically promoting debate. Although the participants acknowledged the controversial nature of many environmental pollution issues, none of the PSTs planned to use the controversies in their science teaching. Only two PSTs (out of eight) spoke about controversies initiated by their students' questions. The PSTs themselves were not familiar with utilizing corresponding pedagogies in their teaching practices.

Although the PSTs are introduced to context based-learning in a STS course in their teacher education program, it does not explicitly concern theoretical models of SSI-based education. From the sample in this study, it seems clear to us that a focus on SSI-based teaching would enrich the teacher education program. A differentiation between context-based learning and SSI-based education should be emphasized in the teacher education program the participants were taking part in. This needs to incorporate learning about various methods for structuring discussions in the classroom, such as role playing, analyzing authentic media from public debates, or mimicking the authentic practices of communication and debate from society (e.g., Eilks et al., 2013a). We suggest not just teaching about corresponding pedagogies by lecturing, but also mimicking classroom situations with the PSTs. This would allow them to develop self-confidence and self-efficacy, as has already been suggested by Burmeister and Eilks (2013) in the field of education for sustainable development.

This study has several limitations. The number of students is limited and the participants all came from the same teacher education program. Further research into other science teacher training programs in Indonesia might reveal how representative this case study really is. Research might also reveal the program's influence on the teaching practices chosen by the PSTs, as well as the influence of the supervising in-service teachers. Interventions would be needed to see whether a greater variety of pedagogies for SSI-based education would come into play, if the emphasis of the teacher education seminars were to be shifted. The study did not explore in detail the reasons why the PSTs avoided controversies in their teaching. This might be subject to future research.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SN and NP developed the research questions, planned the data analysis, and did the interpretation of the results, and drafted the introduction, methods, and discussion section. IE drafted the introduction, theoretical framework, and limitation of the study. All authors contributed to the article and approved the submitted version.

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PAPER 4

Palm oil-based biodiesel in Indonesia: A case on a socio-scientific issue as a context for engaging students to learn chemistry and about chemistry's societal implications

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Palm oil-based biodiesel in Indonesia: A case study on a socio-scientific issue as a context that engages students to learn chemistry and about chemistry's societal implications

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ABSTRACT

This paper presents a case study examining the current controversial issue of palm oil production for manufacturing biodiesel in Indonesia. The study looks at how this issue was used as a context to teach chemistry at the undergraduate level. The lesson unit promotes general educational skills, which students need to develop in order to become actively involved in societal discussions as scientifically literate and responsible citizens. The study analyses students' views on socio-scientific issues-based chemistry education centered around palm oil-based biodiesel in Indonesia. Most of the students (N=74) considered the socio-scientific issues-based pedagogy to be motivating, relevant, and encouraging for both learning chemistry concepts and preparing them for participation in societal debate.

KEYWORDS

Second-Year Undergraduate, Interdisciplinary/ Multidisciplinary, Problem Solving/Decision Making, Application of Chemistry.

INTRODUCTION

In recent decades, there has been a growing call to contextualize science learning through societally relevant questions.[1] The socio-scientific issues (SSI) science education movement is one of the responses to the call.[2] Several theories underpin and justify SSI-based science education, such as aspects of cognitive and developmental psychology,[3] constructivism and the theory of situated cognition,[4-6] or humanistic theories of education.[7-11]

Along with this development, enhancing students' societal-oriented scientific literacy has been accepted as one of the goals of science education.[12] Strengthening human and societal orientations in the chemistry curriculum have also been suggested.[13] In 2007, Roberts proposed two different visions of scientific literacy, namely Vision I and Vision II. [14] Vision I stresses the importance of scientific content knowledge and related competencies for later application. In contrast to this, Vision II emphasizes the need for students to be engaged in an embedded context where they can learn scientific knowledge in a meaningful way. Currently, a third vision, Vision III of scientific literacy has been suggested.[8,9]. Vision III suggests including a critical view of education. Vision III is related to the human element proposed by Mahaffy[15] in his tetrahedron model for chemistry learning. It is strongly connected to socio-scientific issues-based (SSI-based) science education. It is further characterized by recognizing different levels of complexity in the analysis of humanistic aspects in chemistry education.[7,16] Vision III can be understood as a critical version of scientific literacy which aims at enhancing scientific literacy to prepare the young generation for societal participation and a self-determined and responsible life in society.[8-11] This perspective is necessary, but is often neglected in science education.[1,17]

Constructivism suggests that when science learning is starting from everyday life and societal contexts the learning gains become more meaningful to students.[4] Sadler argued that according to situated learning theory, learning environments or contexts under which the students learn are very important and formed by the learners themselves as the result of their interaction and participation with the context. [5,6] These contexts, in turn, shape the way how the learners engage in an activity, influence what the participants learn and become able to do. SSI-based science education provides contexts for students to learn about societal issues linked to science and technology.[6] Therefore, if science education aims at promoting scientific literacy for societal participation students should be provided with SSIs relevant to their society as contexts where they can practice all the skills they need to become active and responsible citizens in their society.

Thus, SSI-based education is more than just a specific form of context-based learning in science education.[6] It provides a framework for promoting general educational skills via science education in order to prepare students for active involvement in a democratic society.[12] It aims to increase students' skills in making and contributing to informed decisions about SSIs.[18] It seems, however, that few science programs around the world teach learners how science is socially and environmentally relevant to their lives and their roles as citizens. Many students fail to take part in societal debates about science and its technological applications in an informed manner.[1] Therefore, it is important to provide students with learning conditions where they can practice the skills needed to participate in societal debate. Some studies even have described how communication and evaluation skills can be developed among learners in chemistry education in order to enhance critical scientific literacy, e.g. based on role-playing activities.[19-21]

SSI-based science education focuses on controversial and ill-structured problems, which require not only scientific, but also morally-grounded, evidence-based reasoning.[18] SSIs have societal ramifications that require students as future citizens to engage in dialogue, discussion, debate, and argumentation. These factors are associated with character formation.[17] SSI approaches do not only address societal implication of science and technology but also the moral, ethical, emotional, and epistemological development of the students.[3] Furthermore, Zeidler et al.[3] suggest that curricula which use SSIs provide environments in which students become engaged in discourse and reflection which affect their personal cognitive and moral development.

The idea of scientific literacy is also in line with the aim of education for wustainable development (ESD). ESD was established by the United Nation Conference on Environment and development which considered education as critical in promoting sustainable development and enhancing human capacities to address environmental and developmental issues.[22] The United Nations have announced the Decade of Education for Sustainable Development for the years 2005-2014.[23] The Global Action Program on ESD then was established as a real contribution to development and education program after 2015.[24] Moreover, in 2015, the Agenda 2030 was issued based in the 17 Sustainable Development Goals.[25] One of the standalone goals is Quality Education (SDG 4) which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all by 2030, as well as the means to attain the other SDGs. [26] Among the ten targets as the guidance for the countries for a transformative way to a sustainable education agenda, Target 4.7 highlights ESD to ensure all the learners acquire the knowledge and skills needed to promote the sustainable development agenda.[25] How ESD is addressed in the curriculum, teacher training programs, development of teaching and learning materials, and the learning environments is considered crucial to framing the effective application of ESD. [27] Burmeister et al. identified promising modes to integrate ESD with chemistry education, one of them is incorporating controversial SSIs into chemistry teaching.[28] SSIs can be used to incorporate issues of sustainability to increase the relevance of science education.[29] In addressing the issue of sustainability, there is a need to bring all the views of associated stakeholders together, including policy makers, scientists, and the private sector.[30] A study which analysed the extent to which the ideas of SDG 4.7 were embodied in policies and curricula across 22 Asian countries describes that the essential competencies such as critical thinking, empathy and collaboration are already suggested, nevertheless those competencies are more justified from the point of enhancing national economic growth rather than as attributes of global citizenry. [31]

Furthermore, SSIs can be used to incorporate issues of sustainability to increase the relevance of science education.[29] Students hardly connect the facts and concepts they learn with real life applications that they fail to recognize the personal relevance of science learning to their lives,[32] and society's future.[33] As a result, students hardly participate in discussions on societal issues about science and technology.[1] Students are more interested in science when they perceive personal relevance of the topics.[34] However, what is considered relevant by the students is not always similar to what the teachers perceive.[35] Science learning should be more relevant from the lens of the students, as well as the society in order to maintain students' interest and motivation.[29] Some studies indicate evidence of the relationship between SSI-based science learning with the promotion of key learning outcomes, including students' interests.[2] Stuckey et al.[32] suggest a model of relevant science education which consists of three dimensions, namely individual, societal, vocational relevance. Among the three dimensions, the societal dimension often is the most neglected one.[1,32] A SSI-based approach is suggested to greatly increase ESD, at the same time combining the three dimensions of relevant science education in teaching.[28-29]

The needs for incorporating SSI-based learning in Indonesia is not only supported by theoretical and conceptual arguments, but also on an empirical base. According to the analysis of the implementation SSI based learning around the world by Genisa et al., it is concluded that the implementation of SSI-based instruction is mostly conducted in developed countries, including the United States, Germany, Sweden, or Japan.[36] Such teaching practices, which use sustainability-oriented SSIs in chemistry education, are infrequently implemented in Indonesia.[37,38] Some of the common reasons for the lack of SSI-based learning in Indonesia are limited teacher knowledge about SSI-based pedagogies and very little experience in their application.[37,39] Science teachers in Indonesia tend not to focus on the controversial nature of SSIs when they teach. Teachers, nevertheless, acknowledge that SSIs might have great potential for engaging students in science class. [38] These studies suggest a need to incorporate SSI-based science teaching and learning more thoroughly in general, and in science teacher education programs in Indonesia in particular.

In this paper, we describe a lesson unit based on palm oil-based biodiesel for a chemistry course designed for pre-service science teachers in Indonesia as an example of SSI-based science education. Palm oil-based biodiesel is not only an authentic problem currently debated in the media in Indonesia. It is also related to the global issue of sustainability. The controversy surrounding palm oil provides a context to teach scientific concepts. It also gives students an opportunity to understand the societal discussions regarding the pros and cons of palm oil use for fuel production. Such discussions are suggested to educate students to make informed decisions and to practice necessary skills to become active in current societal debates. The teaching unit has already been implemented in a science teacher education program at a public university in Indonesia. This paper reports a case study on the intervention. Therefore, the research questions for this study are: 1) What are the students' views on a SSI-based teaching unit on biodiesel use, particularly about the students' interest and perception of relevance? and 2) What are the students' views about how the issue was covered in class in terms of SSI-based teaching?

BACKGROUND AND FRAMEWORK

SSI-based Instruction in Chemistry Education

One framework for SSI-based science education has been proposed by Sadler.[40] According to this framework, SSI-based instruction consists of two core aspects, namely: A design element and the learner experience. The design element consist of four features: 1) Instruction is built around a compelling issue; 2) the issue is presented first; 3) scaffolding for higher-order practices is provided (e.g. argumentation, reasoning, and decision making); and 4) culminating experience is provided, which could be done through multiple pedagogies, such as role play, debate, service learning, etc. In the learner experience aspect, experiences are suggested, so that students engage in higher order practices associated with the negotiation of SSIs, as well as confront scientific ideas and theories, collect or analyse scientific data, and negotiate the social dimensions related to the issue. The implementation of both core elements are shaped by the classroom environment and teacher attributes. There are some classroom environment features which support the implementation of the core elements, namely: students are highly expected for participation; collaboration and interaction; respectfulness is demonstrated between students and teachers; and both students and teachers feel safe within the environment. In order to successfully facilitate SSI-based education, teachers should be familiar with the issue being considered, honest about the limitations of knowledge, intending to engage with uncertainties in the classroom, and to position self as a knowledge contributor. This framework is further developed by Presley et al.[41] which moved the teacher attributes to a more central position in the framework. They also added some recommended additional learning experiences such as confronting the ethical dimension of the issue and considering nature of science themes related to the issue. Other SSI-teaching and learning models have been also suggested by Sadler and colleagues, e.g., see Sadler et al.[42]

This framework is in agreement with the called socio-critical and problem oriented approach to science education, developed by Eilks, Marks and others.[19, 20, 43, 44] This model provides an integrative framework for teaching which answers what, why, how, and when questions in a didaktik model.[10] The first pillar of the model highlights the development of scientific literacy as the central aims of SSI-based teaching (the why-question). The second pillar suggests criteria for the selection of topics which drive instruction (the what-question) and the evaluation of whether or not the topic is aligned with the teaching goals (the why-question). The third pillar serves as guidance on how to make the teaching and learning relevant and motivating to the learners (the how-question), and the fourth pillar provides an organizer for potential teaching sequences (the when-question). According to this framework, teaching has to be started with a current, controversial, societally-relevant, and authentic issue from the society which allows the students to learn science content, whereas at the same time engages them into group discussions and decision making processes. Under this approach, a fruitful socio-scientific issue must meet some specific criteria. The criteria include selecting authentic issues present in public debate, choosing relevant topics which might affect the students' lives, seeking material which provides access to different viewpoints within society, providing problems which are open to debate, and focussing on topics which are related to science and technology. SSI-based science education is suggested to start with authentic media leading via science learning into decision making exercises.

Background on the Production and Use of Biodiesel in Indonesia

The use of fossil fuel resources is strongly debated with respect to global climate change. The possible environmental effects of fossil fuel consumption induced by human activity have become a worldwide concern. Contributions to climate change and worries about declining resources have led to a demand to substitute fossil fuel-based technologies by renewable energy sources for the world's growing population. As part of the response to this issue, many governments across the globe are promoting biofuel use, either in the form of ethanol derived from plant-based starches and sugars, or in the form of biodiesel derived from vegetable oil crops and animal fat.[45] Biodiesel has been suggested as one such alternative energy resource. It is manufactured from edible vegetable oils, including rapeseed, sunflower, soy bean, and palm oil.[46]

Every region of the world has its own preferred feedstock, depending on the geographical conditions in which plants grow. Data from the Food and Agriculture Organization (FAO) of the United Nations for 2018 show that palm fruits are primarily grown in Asia and Africa, sunflowers in Europe, rapeseed in Oceania, and soy beans in the Americas.[47] Asia accounted for 85.6 % of worldwide palm fruit production from 2008-2018, with Indonesia and Malaysia as the largest producers.[48] In Indonesia, small palm farms produce more than 40% of all palm oil area.[49] Some studies have suggested that palm oil development in Indonesia has significantly benefited rural communities and contributed to alleviating poverty.[50.51] This means, however, that up to 60% of palm oil production happens under industrial conditions, with the corresponding risks of deforestation, monocultures and intense land use.

The issue of palm oil production is highly controversial and is the subject of intense political and environmental debate.[52] The controversy about palm oil is authentic, not only in Indonesia, but also internationally. The recently published European Union Delegated Act on Renewable Energy Directive II in 2018 excluded palm oil from its list of sustainable vegetable oils for biofuel production. This decision has increased tensions between the European Union (EU) and palm oil producing countries, such as Indonesia. The EU has argued that palm oil agriculture causes negative environmental impacts (e.g. deforestation) which lead to secondary external effects such as water and air pollution and soil erosion. Such factors reduce the positive effects of sustainable forests for protection of the climate and biodiversity.[52] The current EU policy on biodiesel feedstock is based on the indirect land use change (ILUC) emissions policy. [53] The EU intends to gradually reduce the use of high risk ILUC feedstock for biofuels. Its goal is to end the use of such feedstocks in all EU member states by 2030.[54] There are several models for understanding ILUC emissions.[55] Various models result in different scales of ILUC. Experts, however, express no clear agreement on which model is the best for examining real world impacts. [55] Based on the latest ILUC modelling by the European Commission, released in 2016, palm oil belongs to the highest risk category of fuel sources, compared to other sources of oil such as soy and rapeseed oils.[55, 56]

Checked by online media search engines, palm oil use proved to be a hot topic of debate in the public. Stolz et al.[57] suggested that media presence is one potential indicator to prove the authenticity and societal relevance of socio-scientific issues for science teaching. On YouTube under the rubric of Indonesian palm oil versus the EU, a number of contributions can be found. One TV documentation which was published on March 25, 2019 on YouTube was entitled "*RI melawan diskriminasi sawit Uni Eropa*"[58;] this can be translated as "the RI (Republic of Indonesia) against European Union palm discrimination". As many as 674 comments were logged within 3 months. This finding illustrates how this issue has become a current topic of discussion within Indonesian society. In the video, the Indonesian government criticizes the EU's policy as unfair, because palm oil is the only commodity excluded from sustainable feedstocks used to produce biodiesel. This is despite the fact that other feedstocks such as soy bean, sunflower, and rapeseed also contribute to ILUC. A good example is the new policies being implemented in Brazil, which seek to expand soy bean farming by the clear-cutting of rain forests. Thus, recent EU policy on renewable fuel production is viewed by many Indonesians as a form of discrimination.

Other positions do, however, exist among environmentalists. Various stakeholders have supported criticism of the Indonesian government's policy on palm oil predication, which has given approval to land use changes allowing palm oil plantation expansion. Palm fruit agriculture practices are often associated with deforestation, which endangers the species living in the forests, especially rare species such as the Orang Utan. In one news report,[59] the publishers stated that when the natural forest habitats of the Orang Utan are switched to palm fruit agriculture, Orang Utans will consequently be treated as pests. When they enter palm oil agriculture plantations, they need to be evacuated to escape being killed. Comments to such reports generally scrutinize the practice of palm farming in Indonesian forests, which could result in biodiversity loss. In addition to biodiversity loss, a meta-analysis review by Manik and Halog [60] has shown a significant environmental impact in the life cycle of palm oil-based biodiesel, including effects on global warming, eutrophication, acidification, and the synthetic chemicals release to the environment. Palm oil-based biodiesel sustainability is also criticized because of the negative effects on the well-being of the local or indigenous peoples, who have been living in the rain forest for centuries.[61,62] In a personal interview with the tribal communities conducted by Manik and colleagues,[61] the tribes said that they had been marginalized as soon as the forests were opened for plantations. They not only lost their land and were contaminated by polluted water, they also experienced the loss of intangible cultural heritage.

Despite environmental concerns about palm oil production, palm fruits are viewed as the most effective plants for producing vegetable oils, compared to other sources such as rapeseed, sunflowers, or soy beans.[63] According to Figure 1, palm oil is five to six times more productive in relation to land use than the other feedstocks. We can infer that five to six times more land is required for the production of other feedstocks in order to yield the same amount of oil compared to palm fruit. Since the EU has excluded palm oil as a sustainable biofuel feedstock, the EU must satisfy its vegetable oil demands with other sources. This means the use of extra land acreage to plant non-palm fruit oil sources. A shift from palm oil to other types of oil crops will not always result in positive outcomes for biodiversity.[64] It is, however, not the aim of the EU to replace palm-based biofuels, but to reduce their total use.

Biodiesel blended with conventional diesel (fossil-based) has been suggested as one way to clean up exhaust gas emissions such as carbon monoxide, hydrocarbons,[65,66] carbon dioxide, and smoke opacity.[65] These studies indicate that biodiesel is an alternative type of biofuel, which may decrease greenhouse gas emissions. However, some studies also show an increase in NOx emissions,[65,67]which are a contributor to acid rain.

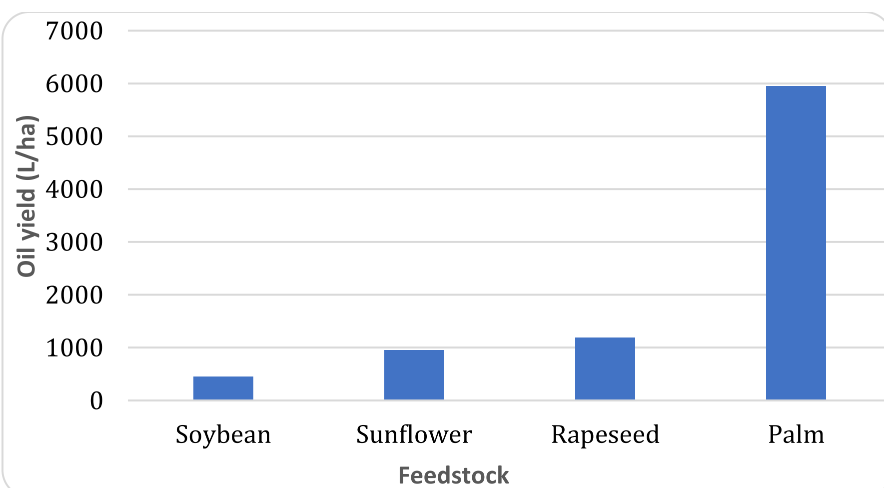


Figure 1 Oil yield of several vegetable feedstocks (adapted from Karmakar et al.[63])

Despite the pros and cons of biodiesel technology, Indonesia has had a mandatory biodiesel program since 2008.[68] It began in 2008 with a 2.5% biodiesel mix in fossil-based diesel, which gradually increased to 7.5% in 2010, 10% to 15% in the period of 2011 and 2015, and 20% in 2016. By the end of 2019, the Indonesian government launched the B30 program (30% biodiesel blends). The biodiesel mandatory blending was established in order to fulfil the government's commitment to reduce greenhouse gas emissions from fossil-based fuels and to lessen the country's dependency on fossil-based fuel imports. At the beginning of 2020, the implementation of B30 was just beginning in Indonesia. Biodiesel policy in Indonesia has been widely reported on by many news outlets. Once again, it has become again a discussion topic in society and the media.

Biodiesel Use as a SSI for Chemistry Education in Indonesia

The previous section discusses how biodiesel fulfils the criteria for selecting SSIs for chemistry education,[43] namely being authentic, relevant, controversial, open to discussion, and related to science and technology. The socio-scientific issue of using palm oil to produce fuel is useful for science learning in context. According to De Jong,[69] learning contexts may function as a motivation, orientation, illustration, or application of concepts. The palm oil-based biodiesel issue meets each of these functions. Since palm oil production is an authentic issue in Indonesian society and is frequently discussed in the media, it can enhance the relationship between science and students' everyday lives. This can motivate students to learn science. The topic also offers personal, societal, and vocational relevance to the students by highlighting and illustrating important practices and professions found in agriculture and industry.

Palm oil can also illustrate why students should learn about the science concepts behind growing and processing palm fruits for the production of oil and related products. There are a number of scientific concepts which can be integrated into the palm oil controversy. For example, undergraduate chemistry concepts which can be integrated are related to organic compounds and reactions, particularly carboxylic acids, esters and trans-esterification. These content is important for teaching about biodiesel production and was already suggested on a lower level for the context of Germany in German upper secondary education.[19] Vegetable oils, including palm oil, are fatty esters, a group of organic compounds based on glycerine. During biodiesel production, the glycerine esters are transformed into methanolic esters with the aid of catalysis. Thus, the palm oil issue can motivate students to learn the science content behind it. This includes the structure, nomenclature, isomers, and properties of the carboxylic acid and esters. Other issues include the various oil extraction processes, trans-esterification for biodiesel production, etc.. At the undergraduate level, more details can be focused on when compared to the lesson plan suggested by Eilks.[19] Furthermore, the issue can orient students with respect to societal discussions. Teaching the science concepts behind biofuel use is also connected to the societal question of whether or not to keep this technology or to switch the transportation sector over to other alternatives such as solar- and wind-based energy. The issue is also a good student introduction into the controversy between Indonesia and the EU. Learners can discuss the risks and benefits of each position. In the end they can make an informed decision regarding the issue, whether or not they agree with Indonesian government program to increase the amount of biodiesel.

SSIs like palm oil-based biodiesel can easily illustrate the close, multi-faceted ties between science, technology, and society.[18] Lesson plan openers can be borrowed from authentic media,[43] such as the news media or YouTube, as has been suggested by Zeidler et al.[18] The pros and cons regarding palm oil-based fuels can be used to engage students in higher-order thinking skills. This is because a discussion of the risks and benefits of palm oil is based on various perspectives, including science, economy, health, the environment, legal ramifications, etc. The topic can aid students in understanding how policy decisions are made. Such decisions are not only based on scientific reasoning, but also on moral aspects and questions of sustainable development. Students can be taught how to critically weigh the risks and benefits, so that they can make an informed decision regarding whether or not they should support the Indonesian government's palm oil biodiesel policy. In the end, learners can reflect upon science concepts and evaluate how they are used in societal decision making.[43] The context can also serve as an arena in which the students learn to accept and appreciate other peoples' points of view and develop open-mindedness. This issue can also enhance their sensitivity and awareness of problems faced by one society with regard to the viewpoints of other societies.[70] In general, the issue discussed here can educate students to think critically and to make responsible, informed decisions. Critical thinking and decision-making abilities are necessary skills for students to be actively involved in societal discussions as scientifically literate citizens.[18]

Another aspect of scientific literacy that can be enhanced through SSI-based learning is the question of the nature of science (NOS).[71] According to Holbrook and Rannikmae,[72] NOS dimensions include understanding of both the NOS and the method of scientific inquiry. The palm oil issue can provoke students to conduct scientific inquiry examining the scientific as well as the societal aspects of the issue. Through the scientific inquiry process, the nature if science is also stressed.[73] Scientific knowledge is understood to result from observations of the natural world, which includes human imagination, inference, and creativity and is socially and culturally embedded. The controversial nature of palm oil use as a fuel can show learners that different people have different opinions about using palm oil as source of biodiesel. This depends on which aspects they emphasize most. Another feature of NOS which this highlights is that the perception of scientific arguments is subjective.

THE INTERVENTION

Table 1 lists the learning purposes and class activities used to introduce the SSI of palm oil-based biodiesel. The class activities are designed according to the design element of the SSI-based education framework of Sadler et al.[40,41] which are also in line with the socio-critical and problem-oriented approach by Eilks et al.[43] There are some parallels to the lesson plan already suggested by Eilks[19]. New features implemented in this unit were, however, a broader and deeper contention, the authentic and current political context of Indonesia, a jigsaw puzzle learning model[74] and the use of an online forum. The learning activity was conducted in three face-to-face meetings of 150 min. each, in addition to one online activity used as an introduction and expert group phase. In the introduction phase, the controversy about palm oil-based biodiesel in Indonesia was presented to the students with the help of authentic media. The students were provided with links to different types of media like a YouTube video called “Bye bye petroleum, say Hi to palm oil” published by CNBC Indonesia.[75] In addition, the students were guided to a website criticizing the Indonesian palm oil industry for environmental reasons. They were also given an online newspaper article about the Indonesian government's plan to implement B30 by January of 2020.[76]

The introduction to the unit was meant to push the discussion towards both scientific concepts and the societal aspects of biodiesel use.[19] Each student was asked to propose questions, either related to the science (chemistry) aspects or the societal aspects of the biodiesel topic. Then the students were divided into eight home groups of four students each for the jigsaw model. Each student in the home group had one specific subtopic to learn and several assignments regarding the science aspects. The introduction and expert group discussions were conducted in an online forum using the university learning management system. The home group discussions were performed in the first face-to-face meeting. This was done to confront the students with the topic prior to having the class discussion and also for reasons of time management. The follow-up activity consisted of the lab work that was conducted in the second face-to-face meeting. Role-playing, debate, and decision-making activities were conducted in the third and final meeting. The decision-making process focuses whether or not the students agree with the governmental plan to increase biodiesel usage. At the end of the lesson, the students are asked to propose a personal decision on biodiesel use and to reflect whether or not this is line with the arguments from the teaching and learning materials and the official policy in Indonesia.

Table 1 Learning Purpose and Activity in the Unit Focusing Palm Oil Use for Biodiesel Production

Phase	Description	Learning purpose	Learning activity
Introduction	The controversy of palm oil-based biodiesel use is presented in order to engage the students with the issue.	Students access authentic media related to the biodiesel issue Students generate questions concerning the issue	Authentic media about the biodiesel policy in Indonesia, e.g. from YouTube, are analyzed by the students. Students formulate questions about chemistry content or societal aspects which they want to explore.
Expert group discussion	The context of palm oil-based biodiesel is used to orient the students to learn about carboxylic acids, esters, and particularly the transesterification process for biodiesel production.	Students are able to: - identify, draw and name the structures of carboxylic acids and esters. - analyze the trends in the properties of carboxylic acids and esters and relate structures and properties. - draw the structures of oil derived from different types of fatty acids. - identify reactants and products and describe the process if esterification and transesterification. - design an experiment for biodiesel preparation using oil commonly found in daily life. - examine the properties of biodiesel and the effects of it or its blends in term of exhaust emission and environment impact.	The students are divided into home groups as heterogeneously as possible with four students in each group. Each student group has one subtopic to learn. All students with the same subtopic form expert groups. Within the expert group, the students discuss and answer the questions related to their specific subtopic in the online forum (four online groups total). Expert group A: Structure, properties, structural isomers, and nomenclature of carboxylic acids/Expert group B: Properties, and isomerism of esters/Expert group C: Structure and nomenclature of esters, as well as the esterification and transesterification reaction/ and Expert group D: Properties of biodiesel and biodiesel's effects on exhaust emissions and the environment.

Home group discussion	The students return to their home groups to share what they learned and to discuss further questions of the home group together.		After discussion in the expert groups using an online forum, each person returns to her or his original home group in order to explain the concepts they have just learned. Each student explains her or his part, the home group discusses the questions related to all of the subtopics. The home group discussions and the following activities are conducted in a face-to-face format.
Lab work	The students produce biodiesel using vegetable oils commonly found in their daily lives.	Students are able to: - conduct practical work to produce biodiesel. - explain the reactions in the process of biodiesel synthesis.	Each group conducts the lab activity to produce their own biodiesel. Students are free to choose any kind of vegetable oils they want to use.
Role-playing debate, decision making	Students discuss the societal aspects of the issue.	Students are able to: - identify the pros and cons given by different stakeholders from within society, such as small farm holders, the palm oil industry, WWF, or Greenpeace. - present arguments in the role-playing exercise and debate session. - make an informed decision about whether or not to agree with the Indonesian government's plan to increase biodiesel blends.	Each home group is assigned a role to play representing a potential group from within society. Four groups should represent pro and the other four con positions. Each group is given several days to write an essay about their position, to justify and defend their position during the debate session. In the debate session, each group presents their position and their arguments based on the results of their analysis. Finally, students make personal decisions regarding to their (dis)agreement with the government's plan to increase the biodiesel blend by weighing multiple aspects, including not only scientific, but also societal factors.

DATA COLLECTION AND ANALYSIS

The study took place between October and November of 2019 at a public university in Eastern Java, Indonesia. Up to 90 undergraduate students who are preservice science teachers (PSTs) majoring in science education from three different classes in their third semester took part in the study. The study was part of a course on "Elements and compounds" which mainly focuses knowledge about inorganic and organic compounds in daily life. The lesson plan on biodiesel use was incorporated in the part focusing organic compounds and reactions, particularly carboxylic acids and esters. All classes were taught by the first author of this paper.

Data collected included both a questionnaire and interviews. At the end of the meeting, the students were asked to voluntarily complete a questionnaire about their opinion of the unit. A total of 74 students responded to the questionnaire. The questionnaire consisted of twenty-eight, five-step Likert items, with answers ranging from strongly agree to strongly disagree. The questions focused on the participants' views about their interests during the lesson, the perceived relevance of the topic, and on how the biodiesel issue was used in the unit. Some of the questions were adapted from Zowada et al.[77] Other questions were developed according to the framework for SSI-based education by Sadler et al.[40,41] The data was analysed descriptively as has been suggested for this kind of developmental oriented practical research.[78] Numbers and percentages were then calculated for the results.

The questionnaire results were enriched by a semi-structured interview with eleven of the students after they completed the questionnaire. The guiding questions in the interview were as follows:

- How aware were you of the complexity of the biodiesel issue (before learning)?
- What did you learn about the most?
- What did you like best?
- What did you dislike? What suggestions do you have for improving the learning?
- Why do you think it is (or is not) relevant to incorporate controversial issues at university or in high school?

The interview was purposely constructed to complement the findings in the questionnaire. The interview participants were identified to represent the variety in the responses from the questionnaire. The interviews lasted for 15-20 minutes. Each was audio-taped, transcribed and qualitatively analysed. From the responses to the questions in the interview, the first author generated inductively common themes/categories according to Mayring.[79] Finally, the first and second author coded the interview transcripts independently according to the coding scheme (Appendix 1). The initial agreement rate was 95%. Some disagreement appeared in one of the students' responses to question 3 and 5. The disagreement was again discussed among the coders until 100% agreement was achieved.

All quotes from the interviews were translated from the Indonesian language and checked by a native speaker in English. The data was provided by the participants on a voluntary basis and handled anonymously. All data collection and handling complies with the legal regulations for ethical empirical research with human beings at the department in question. Permission for data use was provided by the dean of the faculty.

FINDINGS AND DISCUSSION

Students' Views about Their Interests and the Relevance of the Lesson Plan

Figure 2 provides an overview on student feedback about their interests and their perception of the relevance of learning about palm oil-based biodiesel, including both the science content and societal the controversy. The majority of the students agreed or strongly agreed that they were motivated to learn the science concepts behind biodiesel production and use (84%) and the social aspects related to it (89%). The biodiesel issue was introduced at the beginning of the unit. The participants were asked to propose questions about any science or social aspects they want to know about regarding biodiesel. Table 2 shows some of their queries. The questions covered the chemistry aspects such as the structure, property, and preparation of biodiesel. They also addressed the effects of biodiesel on the environment and on machine performance. Also included were questions about alternative sources for biodiesel production and alternative forms of renewable energy. In addition, the learners also wanted to know about social aspects such as environmentalists' reasons for concern about biodiesel production. We can clearly see that the biodiesel issue motivated the participants to learn science and discuss the societal aspects, as was also reported by Eilks in a previous study with secondary school students.[19]

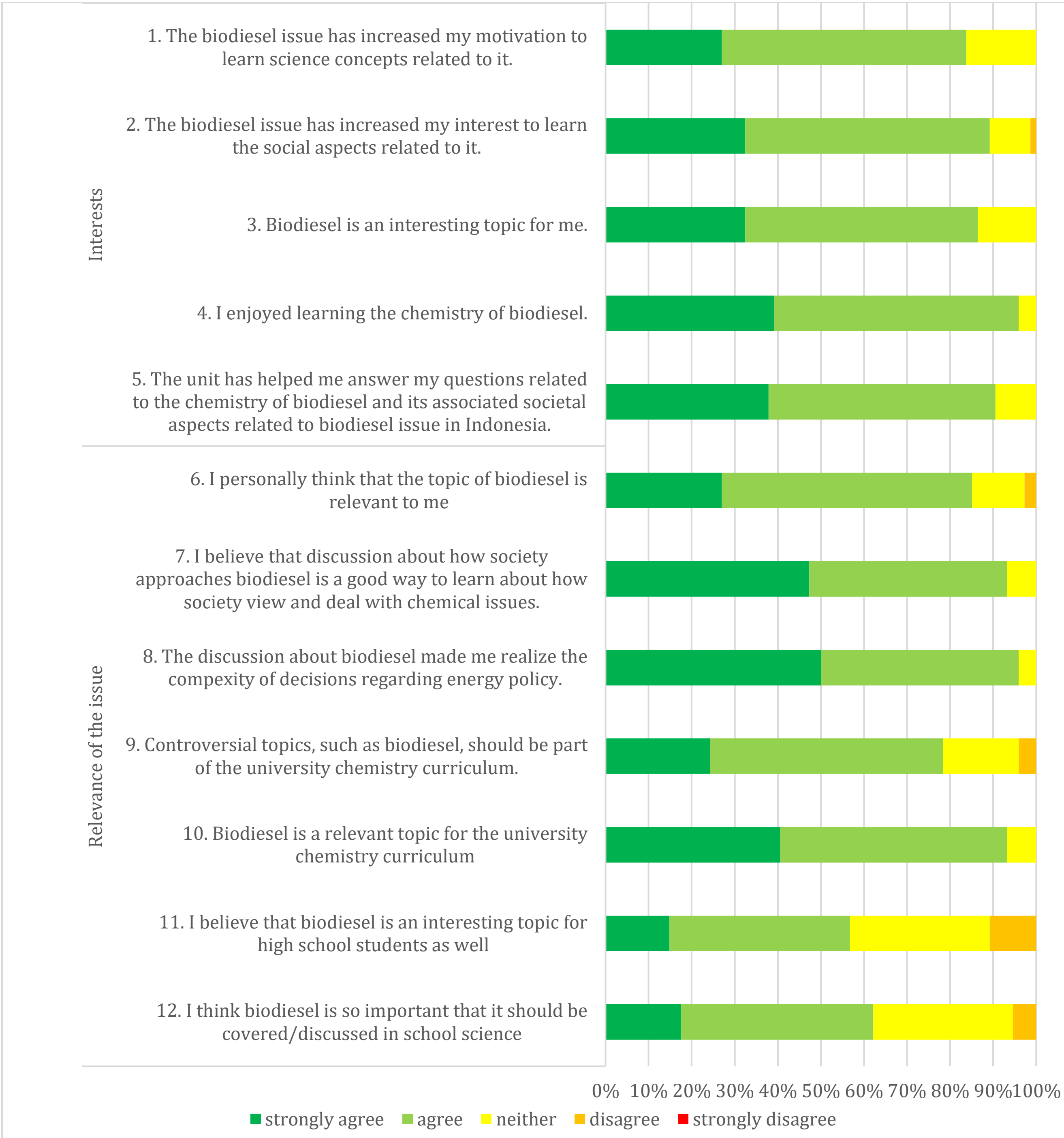


Fig. 2 Students' feedback about their interests and the perceived relevance of the issue

Table 2. What Students Queries to Learn on Biodiesel

No	Category of questions	Example questions
1.	Related to structure	How is chemical structure of biodiesel? What groups of organic compounds into which biodiesel can be classified? How is the preparation of biodiesel?

		Which reactions the reactants undergo to form biodiesel?
2.	Related to biodiesel properties	What are the gas emissions caused by biodiesel usage? How are the effects of biodiesel on car performance? How are the effects of biodiesel emissions on the environment
3.	Alternative source	What other sources for biodiesel beside palm oil? What are other sources/ types of renewable energy?
4.	Social aspect of biodiesel	What are the reasons given by environmentalists opposing the biodiesel policy? What are the societal controversies regarding the biodiesel issue?

Most of the students (87%) considered biodiesel to be an interesting topic. Almost all of the participants (96%) expressed satisfaction in learning about the chemistry of biodiesel and its societal implications. This was supported by the interview data collected in part two of the lesson. Analysis indicated that most of the students stated that the parts they liked best were the biodiesel preparation exercise and the final debate on the topic. Typical examples were: " I liked the biodiesel synthesis … In the lab work, I learned how to make biodiesel from various vegetable oils, including from waste oil"; "I liked the debate session in which every group was free to choose any position to represent and we were encouraged to justify our position with as many evidence as possible… It made me explore many things, not only the science aspects".

A majority of the students (91%) agreed or strongly agreed that the lesson plan had answered their questions regarding the scientific and societal aspects of Indonesia's biodiesel policy. This means that the lesson helped them answering questions about what they wanted to learn regarding the content and societal aspects of biodiesel use, as given in Table 3. It is evident that SSI-embedded instruction has potential for generating student interest and enthusiasm.[2,40] Although most students mentioned that they liked the lesson, two students revealed in the interview that they were disappointed with the overall level of chemistry content. They said: "I wanted to learn more about the structures, the reactions, and all of the chemistry of biodiesel, but we spent so much time on the societal discussion". Such a position was expressed only by a minority of the students. It was, however, that the lesson plan covered all the intended chemistry content as suggested in the curriculum, such as the structure and properties of carboxylic acids and esters. This quote, might indicated that there are some students still thinking that chemistry education should focus the learning the scientific content only. Societal discussions were something new and might be considered by some students as distracting them from learning the pure chemistry content.

A large number of students (85%) also agreed or strongly agreed that the biodiesel issue was perceived as personally relevant to them. A majority of the students (93%) agreed or strongly agreed that the discussion about how society approaches biodiesel showed them how society views and deals with chemistry issues. A total of 96% of the learners agreed or strongly agreed that the biodiesel discussion made them realize the complexity of decisions on energy (biofuel) policy. During the interviews, all of the students admitted that they had not been aware of the complexity of the issue before the lessons: “I did not know much about biodiesel, all I knew is that it is an alternative form of energy. However, I didn’t realize that there are so many complex issues in it”. So, the unit made them realize the overall complexity of the issue. In general, the lesson made the students realizing the personal relevance to their lives, [32] and society’s future.[33] In addition to that, the lesson has addressed the societal dimension of relevant science education that is the mostly neglected one among the three dimensions of relevance proposed by Stuckey et al.[32]

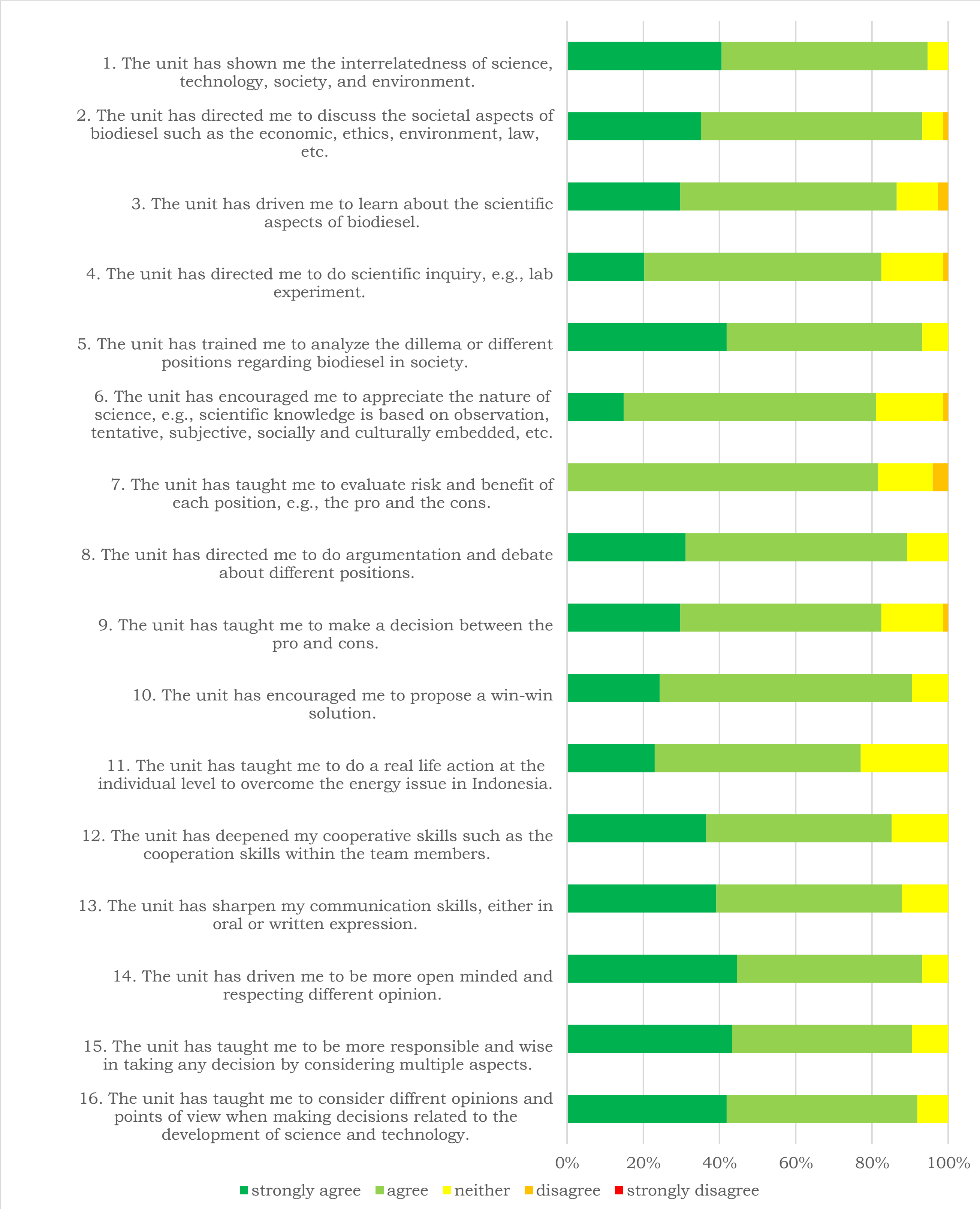
Although the predominant part of the students (93%) acknowledged that biodiesel is a relevant issue for the university chemistry curriculum, some students (22%) remained neutral or disagreed about integrating controversial topics such as biodiesel use as a part of a university curriculum. Even more students (43%) were neutral or even disagreed with the idea that biodiesel could be an interesting topic for high school students. A total of 38% of the learners were neutral or did not think that biodiesel use should be covered in school science. But, none of them strongly disagreed on this point. Overall, the participants saw the topic as more important for a university chemistry curriculum, as compared to school science teaching. When asked in the interview, the common reason given was that high school students were not considered being ready to talk about complex, controversial issues. Consider the following quote: “For high school students, I don’t think they have sufficient knowledge or the skills to address an issue which is very complex such as biodiesel.” This is in line with findings by Kara [80] and Nida et al.[39] These studies showed that many teacher candidates in Indonesia are concerned about high school students’ level of knowledge and overall ability when handling SSIs. Another reason that the PSTs in our study mentioned was that they thought that high school students needed to focus more on the science concepts. One participant summarized this as: “at the high school level, the learning should emphasize science content”. For that reason, PSTs, in their teacher education program, should receive education about the importance of SSI-based education for students’ learning.

Students views of how the issue was covered in class

According to the participants' responses in Fig. 3, they mainly agreed or strongly agreed (87%) that the lesson plan drove them to learn the main scientific aspects behind the issue. They also agreed or strongly agreed (82%) that the unit led them to perform scientific inquiry such as proposing questions, designing and conducting a lab experiment, analysing data, presenting results, reasoning, etc. During the lab work, students worked in groups to manufacture biodiesel from any oil source that they chose. Most of the groups used palm oil as the source, however, several groups experimented with waste cooking oil. The lab work procedure was kept extremely brief, so that the students were forced to design the details of the experiment by themselves. They had to specify how much oil, catalyst, and alcohol should be used according to the proper reagent ratio for the reaction to take place. In the interviews, three students criticised the lab work for not giving the procedure in sufficient detail, unlike the prescribed lab procedures they usually received. They felt that it took them too long to prepare the experiment, as shown the following quote shows: "There is no detailed step-by-step procedure for the lab experiment, so that we needed to spend a lot of time to design it."

As many as 81% students agreed or strongly agreed that their appreciation for the nature of science had increased. They had learned that scientific knowledge is based on observation, and is tentative, subjective, and socially and culturally embedded. Indeed, SSI-based instruction can encourage students to think about NOS questions.[41] More students (93%) agreed or strongly agreed that the unit had directed them to discuss the societal aspects of biodiesel usage such as those concerning economics, ethics, the environment, law, etc. Nearly all of the students (95%) agreed or strongly agreed that the lesson illustrated the interrelatedness of science, technology, society, and environment. A large number of participants agreed or strongly agreed that the exercise had encouraged them to analyse the dilemma or the different societal positions regarding biodiesel, as well as evaluate the risks and benefits inherent in each position (93% and 88%, respectively):

> "In addition to learning the chemistry of biodiesel such as its structure, how it is prepared, and the exhaust gases and their effects on the environment, I also learned to view the issue from different angle, either pro or con, so that I can consider the risk and benefit from both sides when proposing a solution to the issue".



495 Figure 3. Students' view regarding how the biodiesel issue was covered in class

These results indicate that the discussion and negotiation the students conducted was based on multifaceted aspects. They were not only based on scientific consideration, but also on societal aspects. This is in line with Zeidler,[17] who found that discussions regarding the societal ramifications of SSIs require evidence-based reasoning as well as moral reasoning.

The students mostly agreed or strongly agreed (82%) that the lesson taught them to analyse the dilemma and the different positions regarding biodiesel in society. Most of the students said that they agreed or strongly agreed that they had engaged in activities promoting higher-order practices such as argumentation/debate (89%), or decision-making (82%). In effective SSI-based instruction, it is necessary for students to be involved in activities that enhance higher-order practices (e.g., reasoning, argumentation, decision-making or position taking.[40,41] Furthermore, the decision-making process that the students learn through SSI can contribute in shaping a sustainable future as the focus of education for sustainable development.[28] In the interviews, for example, one of the students stated: "In the role-playing exercise, I represented the government". I know the potential and risks of biodiesel mandatory policy. I learned how to make policy which is more eco-friendly, more sustainable". Another student said: "Students have a role as agents of change. We can critically think about governmental policy or at least we can take part in criticising or watching over governmental policy".

The students agreed or strongly agreed (91%) that the lesson had encouraged them to propose solutions for the future. At one of the activities, the students were asked to propose their position on potential solutions for the future. Some students argued that palm oil can be used as a source for biodiesel, however, the amount of biodiesel as fuels might keep limited. Some suggested that the government should invest more in alternative types of renewable energy technologies such as solar energy, wind based power plants, etc. Some others considered the transportation policy to reduce the number of private cars and stressed the importance public transportation. In addition, some students also argued about more sustainable agriculture practices, e.g., by extensification.

A smaller, but nevertheless a significant number (77%) agreed or strongly agreed that the unit taught them to perform real-life actions at the individual level. This is possibly because the students had not yet encountered biodiesel directly in their own lives. Many Indonesian transportation modes, either private or public, do not yet employ diesel engines, or students do not reflect on the type of engine in public transport vehicles. So, some students might not recognize many things they can personally do with respect to biodiesel fuel usage. This is in line with the findings reported by Lee et al.[81] PSTs tend to approach SSIs with emotion and sympathy, yet fail to see themselves as major agents who are able to actively contribute to resolve large-scale societal issues. This unit did not specifically emphasise the students' contributions at the individual level to address the general issue of energy use in Indonesia. Therefore, an activity explicitly doing so might a good add-on in the future. This would provoke participants not just to propose ideas at a normative level, but also to take personal action to resolve the energy problem at the individual level.

Most of the students (85%) agreed or strongly agreed that the lesson had deepened their cooperation and collaboration skills. When they learned the chemistry concepts in the expert or home groups, they felt encouraged to work together to answer the questions and perform the tasks. In the role-playing and debate session, they also felt encouraged to support their group's position with evidence and justifications, even though they might have had different personal positions. Furthermore, 88% of the students agreed or strongly agreed that the unit sharpened their communication skills, either in oral or written form. The literature shows that SSIs can increase students' communication skills by enhancing peer interactions, provoking reasoning, and constructing shared social knowledge.[82] Even more students (93%, 91%, 92%, respectively) agreed or strongly agreed that the lesson: 1) made them more open-minded and respectful of differing opinions, 2) forced them to be more responsible and wise when making decisions by considering multiple aspects, and 3) required them to consider different opinions and points of view when making decisions related to the development of science and technology. Statements such as "I become more open-minded to different positions, because we viewed the issue from multiple perspectives" are commonly found in the interviews. This is also supported in the literature. SSI-based education has already been shown to raise students' awareness and sensitivity to topics [18, 40, 70, 83] and to enhance their appreciation of varied viewpoints and perspectives.[70]

CONCLUSION

The SSI of palm oil basis for fuels is an authentic, controversial issue in the country of Indonesia. It is directly related to science and societal aspects which can be used as a teaching context, through which students can view palm oil usage with a broader lens. The findings in this study suggest that SSI-based instruction on biodiesel is viewed as motivating, relevant, and encouraging when students are learning about the chemistry elements and the societal implications of the issue. This falls in line with several previous studies focusing on the chemistry of biofuels in a broader, societally-oriented approach with an enriched pedagogy.[19,84,85] The teaching approach in this study, however, was developed for and implemented in a different educational level, and in a different cultural, socio-political and educational context. To our knowledge, there is no study on a societal-oriented teaching approach about the use of biodiesel related to organic chemistry (e.g., carboxylic acids and esters) at the undergraduate level, especially not under inclusion of engaging students in reflecting the societal implications of biodiesel usage in a certain national policy controversy. From this study it seems to be important to engage undergraduate students with societal discussions, particularly using the issues which are socio economically important and ethically, morally connected to the society where the students live. The developed lesson plan made science learning more relevant in the eyes of the students and for society's future. In addition, the learning has potential to support students to make an informed decision and to responsibly and sustainably as a scientifically literate citizen, as suggested by Sjöström and Eilks,[9] as well as laid down in Target 4.7 of the SDGs which stresses ESD to ensure all the learners to obtain knowledge and skills they need to promote the sustainable development agenda.[25] In addition to that, the lesson can show to practice a different way of teaching if the students are prospective chemistry teachers. In the current case study changes in the curriculum and an enriched pedagogy were carried out in parallel. From the data collected it would seem that both changes were positively perceived by the participating students. A novelty effect may also have played a role, but such an effect cannot explain the overwhelmingly positive responses given by the students.

In general, this study - like many others - shows that authentic and controversial SSIs can be a positive stimulus to get students to learn chemistry. This study is one of the first on SSIs in the educational context of Indonesian undergraduate chemistry teaching and teacher education. As such, it provokes further research questions about the effectiveness of content learning and the development of the necessary educational skills mentioned above. It also stresses the question about differences in curricula needed for various educational and cultural environments. The questions rises in which way teaching about renewable fuels in chemistry education needs to be contextualized in the foreground of different educational, cultural and socio-political environments. For the case of Indonesia, it also requires the development of further examples and studies how they might be implemented, and how they can be transferred to the secondary school teaching level. Further research and evidence-based curriculum development are needed, as is the professional development of teachers to help them to incorporate SSIs into chemistry education[86] and into the educational context of Indonesia. Sustainability-oriented SSIs, e.g. on biofuel usage, have repeatedly proven their potential to enrich chemistry learning by focusing not just on learning about chemistry itself, but also on its societal and political implications.[19, 84, 85] This remains a neglected field in the teaching of chemistry, both at the secondary school and undergraduate level, particularly in the case of Indonesia. Further research and curriculum innovation are needed in this area.

This study has several inherent limitations. It is specifically bound to the educational context of only one university in Eastern Java and examined only three classes. It focuses on a single topic in a specific pedagogical setting and it is limited basically to the students self-reports. The feedback of the students is, however, so clear that it points out a clear direction for needed change in Indonesian chemistry teaching and teacher education. Therefore, it might be useful to develop further examples and to look deeper into this kind of intervention cases studies, for Indonesia and any other country, by broadening the practice fields involved and by using multi-facetted evaluation and assessment approaches.

ASSOCIATED CONTENT

Supporting Information

The Interview Coding Scheme (DOCX)

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PAPER 5

Genetically vs. Non-Genetically Modified Rice: A Socio-scientific Issue for a transformative learning approach

Book chapter in I. Eilks, S. Markic & B. Ralle (eds). Building bridges across disciples for transformative education and a sustainable future, Aachen: Shaker (2018), 225-230

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Genetically vs. Non-Genetically Modified Rice: A Socio-scientific Issue for Transformative Education

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This paper presents ideas and justification how the topic of genetically modified rice might be used as a socio-scientific issue for transformative education in Indonesia. The approach intends to contribute transforming science learning from a less relevant, content-based to more relevant, contextualized practice. This paper acknowledges the importance of Socio-Scientific Issues (SSI) for relevant science education and combines it with ideas of Education for Sustainable Development (ESD). A discussion is provided about how the issue of genetically modified rice fulfils the criteria of a good context for SSI-based education, namely authenticity, relevance, controversial character, openness to debate, and relatedness to science and technology. A framework for SSI-based learning operating socio-critical and problem-oriented science education about genetically modified rice is suggested. The suggested approach is particularly reflected on how it can contribute to the development of students' skill in evaluation and communication as well as how it possibly increases the relevance of science teaching.

Relevant science education and socio-scientific issues

Science and science education are not very popular among many students (Hofstein, Eilks, & Bybee, 2011). A reason is suggested in the fact that traditional science learning is often considered as being irrelevant among the students (Holbrook, 2005). School science curricula are suggested to be overloaded and too much exclusively focusing learning of facts and theory (Gräber, 2002; Lyons, 2006). As a result, students are unable to connect the facts and concepts they learn with real life applications, thus they do not acknowledge the personal relevance of science learning to their lives (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013) and society's future (Eilks & Hofstein, 2015). Consequently, they may fail to take part in discussions on societal issues regarding science and technology (Hofstein et al., 2011).

Some studies indicate that students are more interested in science if the topics are perceived as being personally relevant to them (Bybee & McCrae, 2011). What is perceived to be relevant by the students is, however, not always the same as what teachers think (De Jong & Talanquer, 2015). Therefore, science teachers are urged to make their teaching more relevant from the perspective of the student and of society,

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in order to maintain students' interest and motivation in learning science (Eilks & Hofstein, 2014). In general, science teaching should be transformed from less relevant, content based into relevant, contextualized teaching (Eilks, Rauch, Ralle, & Hofstein, 2013).

Stuckey et al. (2013) revealed that relevance in science education has diverse meanings and sometimes, in the literature, overlaps with other socio-psychological constructs, such as interest, meaningfulness, need, or real life effects for the individual and society. A general definition of relevance in science education has been missing for a long time. Stuckey at al. (2013) recently suggested to connect the understanding of relevance in science education to the idea of consequences and fulfilling personal needs. Their model of understanding relevant science education covers intrinsic and extrinsic components and consists of three different dimensions, namely individual, societal, and vocational relevance.

Among the three dimensions of relevance in science education, the societal dimension is often the most neglected one (Stuckey et al., 2013). One theory that justifies a stronger societal focus of science education is the concept of education for sustainable development (ESD) (Burmeister, Rauch, & Eilks, 2012). The focus of ESD is to prepare the next generation to act responsibly as citizens for shaping a sustainable future. Students should become able to actively take part in society and to help influencing the future in a sustainable manner. Students should possess competencies to act for the concept of sustainable development, not only for themselves, but also for the future society (de Haan, 2006).

Many studies give emphasis to the importance of science in sustaining the economic prosperity of the modern world, thus rationalizing the learning of science as essential for any sustainable development of the future (Burmeister et al., 2012), but also for active contribution in society and to societal issues as literate citizens (Holbrook & Rannikmae, 2007; Roth & Lee, 2004). ESD might offer a solution since its goal is not only to prepare students to have adequate scientific knowledge and skills for a self-determined life in society, but also to behave as responsible citizens actively involved in relevant socio-scientific discussions. A socio-scientific issues (SSI)-based approach is suggested to best increase ESD and the relevance of science education and students perception thereof (Burmeister et al., 2012), as well as for integrating the three dimensions of relevant science education in teaching (Eilks & Hofstein, 2014).

Criteria for selecting potential SSIs for science learning are authenticity, relevance, controversial character, openness to debate, and relatedness to science and technology (Marks & Eilks, 2009). One of the societal issues in science that is highly relevant to human life is biotechnology. An example that is authentic and relevant for Indonesia is the use of transgenic biotechnology in agriculture, such as production of rice as the main food source. This issue is a relevant stance for science education, especially in rice-consuming countries. The following sections discuss the authenticity, relevance, controversial character, openness to debate, and relatedness to science and technology of genetically modified rice issue that can be used as a relevant socio-scientific issue to be handled in science education in rice consuming countries, such as Indonesia.

Genetically modified rice as a topic

Rice is one of the most important crops in the world because it is one of the main source of carbohydrates. Its production is crucial for the survival of the world's population where a majority bases its nutrition on rice. Asia produces and consumes 90% of the world's rice (Maraseni et al., 2017). Indonesia is the largest per capita rice consumer country among the three largest Asian populations, namely China, India and Indonesia.

The production of rice for meeting the food needs of the population is facing various challenges, such as decreasing availability of land for rice farming due to the conversion of paddy fields into residential and industrial land, the number of diseases or pests that attack rice plants, or changing conditions caused by climate change. Increased yield of rice productivity can be done through the utilization of transgenic biotechnology to produce genetically modified (GM) rice. GM crops are developed not only to improve crops production and to produce crops which are resistant to pest and decease, but also to improve its nutritional value (Moghissi, Pei, & Liu, 2016).

People who have fulfilled the needs of macronutrients in the form of carbohydrates, fats, and proteins also need micronutrients. Micronutrient deficiency is commonly experienced by the population where rice is the major staple food (GRiSP, 2013). Transgenic biotechnology can bridge the problem of low micronutrients by producing rice varieties whose amount of micronutrients is higher than in conventional rice. Therefore, transgenic biotechnology may not only play a role in terms of increasing quantity, but also in producing staple foods that is more functional for health.

Despite the promising solution provided by transgenic biotechnology in fulfilling food demand, it must be applied wisely by paying attention to the local context and its potential long-term effects. Opponents of transgenic biotechnology are concerned about its possible risks toward human health, natural biodiversity, and society (Nuffield Council on Bioethics, 2004). The utilization of transgenic biotechnology must also consider environmental aspects and questions of sustainable development. Any chemicals and changed crops brought into the natural environment need to be assessed concerning any risks on the natural fauna and flora, making the use of transgenic biotechnology a societal-relevant, yet controversial issue. Moreover, there is no scientific consensus on the safety of GM crops on human health and environment (Hilbeck et al., 2015). This makes GM foods an issue open for debates.

The pros and cons on genetically modified crops are a hot topic that can be easily found in the media, either online or print, including scientific papers. The debate involves many stakeholders, namely industry, the scientific community, civil society, and policy which encompasses economic, health, environment, and social issues related GM crops (Weisenfeld & Hunck-Meiswinkel, 2005). One example of an authentic issue regarding rice agriculture is Golden Rice. Golden Rice is genetically modified to increase its vitamin A content. The proponents of Golden Rice view it as a new hope for combating vitamin A deficiency which is prevalent in societies whose rice is the staple food, whereas the opponents doubt the technical, economic, and social effectiveness of Golden Rice (Weisenfeld & Hunck-Meiswinkel, 2005).

Socio-critical and problem-oriented science education on genetically modified rice

Transgenic biotechnology as a new form of applying science is closely related to society so that the learning on biotechnology should be societally contextualized. One corresponding curriculum approach is socio-critical and problem-oriented science education (Marks & Eilks, 2009). The approach is closely connected to the issue of the relevance in science education and ESD (Eilks & Hofstein, 2014). Socio-critical and problem-oriented science education is a holistic and critical connection between science, life and society and thus can contextualize teaching and learning on biotechnology in a meaningful way. It is in line with the suggestion of using socio-scientific issue in science education as stated by Stuckey et al. (2013, p. 27): "*This form of science education has been suggested as helpful for students to learn about the interrelationship of science and society, while simultaneously developing skills for participating in societal debates and decision-making processes.*"

Socio-critical and problem-oriented science education is set up by providing students with controversial issues taken from students' everyday life and society that can be used to provoke discussion and decision-making processes, and at the same time help learning science content knowledge (Eilks, Marks, & Feierabend, 2008; Marks & Eilks, 2009; 2010). This approach can motivate teachers and students in science class, as well as contribute to develop communication and evaluation skills, which are very important in educating responsible citizen for the future (Hofstein et al., 2011). This is in agreement with what Eilks et al. (2008) state that the core objectives of the socio-critical and problem-oriented approach in science teaching are:

- to increase students' interest in science and technology, and to display the relevance of science in societal discussions and decision making
- to make the students aware of their own interests, to motivate students to develop self-interest (either as consumers or within political decision making), and to stimulate individual decision-making processes,
- to promote students' competency in the critical use of information and in their reflection upon why, when and how science-related information is used by affected groups or for public purposes, and
- to promote student-active science learning motivated by relevant, contentious socio-scientific issues.

The debate on genetically modified rice can be used to provoke students in addressing how to deal with rice demand and suggest solutions or alternative ways to produce high quality, safe rice to fulfill the society's need based on scientific data as stated by Eilks and Hofstein (2014, p.10) "*They are forced to think about the pros and cons of certain issues, to suggest solutions and to recommend a compromise solution based on scientific data*." ESD-driven science education using SSIs can contributes to individual, societal, and vocational relevance (Eilks & Hofstein, 2014). At the individual level, the rice transgenic biotechnology issue can contribute in stimulating students to think about the environmental challenge of producing rice using transgenic biotechnology. At the societal domain, students can learn how to make decisions on the local or national levels whether to accept or not food made by transgenic biotechnology. At the vocational level, students might be introduced to careers that they may embark in future regarding biotechnology, such as biologists, chemists, plant breeders, environmentalists, even other non-science professions like politicians, non-government workers, etc.. This can show students that learning science is very relevant for them. Even if they later do not embark in science-related job, to whatever role they will have in the future, they still need scientific knowledge and skills to function as scientifically literate citizen.

Conclusion

Genetically modified rice is an authentic, controversial issue that has potential for socio-scientific discussion as a transformative education approach. It may help transforming science education from less relevant, content-based learning into more relevant, contextualized education. The socio-critical and problem-oriented learning on genetically modified rice can be designed to promote students' process skill in discussion and decision-making, such as communication and evaluation skills, which are essential in educating responsible citizen. Corresponding curriculum development is now ready to start.

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