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Spatial and social relevance perceptions by pre-service teachers of learning about oil palm management as a local or nonlocal socioscientific issue

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Introduction: Pre-service teachers (PST)' perceived relevance of learning about environmental socioscientific issues (SSI) can be an indicator for their motivation to act as change agents. Until now, science education (research) has often addressed the relevance for learning about SSI insufficiently differentiated regarding spatial and social dimensions. However, theoretical frameworks suggest that such differentiation enhances meaningful teaching and learning. This study investigated how local, national, and global subdimensions of spatial relevance as well as individual, societal, and professional subdimensions of social relevance influence PST' relevance perceptions of learning about SSI. Additionally, we examined how relevance perceptions vary depending on whether the SSI is local or nonlocal to PST. We specifically investigated Indonesian PST' relevance perceptions of learning about oil palm management (OPM), a local SSI for PST of one university and a nonlocal SSI for PST of two other universities.

Methods: The PST participated in a 5-week socioscientific inquiry-based educational unit on OPM in curricular courses ($N = 111$). We followed a mixed-method approach, employing measurements of utility value. Utility value is a specific construct of perceived relevance, which refers to the usefulness of learning about objects for a person's life, profession, and society. Quantitatively, we conducted pretest-posttest-follow-up surveys on PST' perceived utility value for learning about OPM over time. Qualitatively, we analyzed responses to a utility value reflection task that was integrated into the unit.

Results: Overall, the unit increased PST' utility value over time. Local PST perceived lower utility value for learning about OPM than nonlocal PST. In the task responses, local PST referred more to the local subdimension, whereas nonlocal PST referred more to the national subdimension. Nonlocal PST' societal and professional utility value increased stronger over time compared to local PST.

Discussion: We discuss potential reasons for local PST' lower relevance perceptions, e.g., personal experiences and skepticism through local embeddedness. Our findings on relevance perceptions among local and nonlocal PST underscore the importance of spatial- and

social-sensitive SSI education. We point out practical implications for promoting relevance perceptions considering local and nonlocal PST. Moreover, we suggest research directions for more differentiated relevance research in science education.

KEYWORDS

relevance, utility value, socioscientific issue, teacher education, Indonesia, sustainable development

1 Introduction

Conventional crop cultivation is a positive driver of economic growth. At the same time, it can have negative impacts on livelihoods and the environment (Grass et al., 2020). Thus, there is a growing need for sustainable crop management. Science-based knowledge on socioeconomic-environmental win-win opportunities is available for multiple crops in different regions (e.g., Wurz et al., 2022; Iddris et al., 2023). For example, mechanical weeding combined with reduced fertilization as oil palm management (OPM) practices—compared to conventional management—can enhance biodiversity and ecosystem functions in industrial plantations, while farmers can make profits and reduce health hazards (Iddris et al., 2023). Science-based knowledge on sustainable OPM practices is highly important for the policymakers and stakeholders in the agricultural sector, communities, and society at local, national, and global scales.

One way to communicate science-based knowledge on sustainable crop management to society is through formal education. Beyond school and vocational education, teacher education is particularly promising. Pre-service teachers (PST) play a crucial role in promoting sustainable crop management, as they can act as change agents and multipliers for sustainable development (Winter et al., 2022). In the context of climate change education, Winter et al. (2022) emphasized the need to qualify PST specifically for the challenging task of acting as competent and efficient change agents and multipliers.

Socioscientific issue (SSI) education can foster competencies needed by learners and PST to address SSI (e.g., Nida et al., 2021; Winter et al., 2022). SSI are complex and controversial real-world problems at the intersection of science and society (Sadler, 2004), such as OPM. The core goal of SSI education is to enhance learners' scientific literacy and thereby competencies such as reasoning, decision-making, and perspective-taking (Sadler, 2004; Herman et al., 2021). Appropriately engaging with various dimensions of SSI (e.g., scientific, social, economic, political, temporal, local, and global) is crucial for enabling learners to develop such competencies (Sadler, 2004; Sadler et al., 2017). Despite its importance, the social dimension of SSI is often neglected or unsystematically addressed in educational practice (Friedrichsen et al., 2021; Nida et al., 2021).

A holistic understanding of SSI is essential for effective SSI education (see Tuncay et al., 2012). Addressing perceptions of learners and (prospective) educators is crucial in this regard (Tuncay et al., 2012; Winter et al., 2022; Yli-Panula et al., 2023). For example, the locality of SSI, which means the SSI can be local or nonlocal to a person, can influence perceptions. Perceptions of environmental SSI are shaped by experiences, knowledge, beliefs, and concerns differently (Duan and Fortner, 2005; Tuncay et al., 2012; Yli-Panula et al., 2023).

Perceived relevance of learning objects is a key motivational factor for effective teaching and learning (Stuckey et al., 2013; Priniski et al., 2018). Understanding PST' relevance perceptions of SSI education can provide valuable insights into how future educators perceive and engage with SSI such as OPM. However, in SSI education, there is limited differentiated research on PST' relevance perceptions regarding different dimensions and how the locality of the SSI for PST impacts these perceptions.

Studying relevance dimensions can help to deeper understand how PST perceive the relevance of learning about SSI. If (future) educators perceive only little or no relevance of the learning objects, it is unlikely that they will effectively learn, teach, and foster learners' relevance in this regard (Stuckey et al., 2013).

Our study addresses this gap by exploring Indonesian PST' spatial and social relevance perceptions of learning about OPM, which represents either a local or nonlocal SSI to the PST. The purpose of this study is to generate knowledge—using a mixed-methods approach—to motivate and enable future science teachers for meaningful SSI education to promote sustainable development.

2 Theoretical background: relevance-related research regarding socioscientific issue education

Perceived relevance refers to a person's subjective perception of a meaningful connection between an object (e.g., topic or activity) and the person's life (Priniski et al., 2018). It can range from low to high magnitude and it can be located on a continuum from personal association to identification (from low to high personal meaningfulness) (Priniski et al., 2018). Promotion of relevance perceptions is closely related to the promotion of interest and the enhancement of short- and long-term learning outcomes across different educational levels and contexts (Stuckey et al., 2013; Priniski et al., 2018; Hecht et al., 2021).

However, there is no agreed-upon understanding of relevance across disciplines (Stuckey et al., 2013; Priniski et al., 2018). Even within specific research fields, relevance is defined and used in diverse ways (Stuckey et al., 2013; Priniski et al., 2018). Therefore, defining the construct of relevance, drawing relations to theoretically developed frameworks and aligning them with (adapted) measures are crucial for appropriately assessing relevance.

2.1 Relevance in science education

Beyond educational psychology research, relevance is often used "inadequately conceptualised" in science education

(Stuckey et al., 2013, p. 1). It frequently serves as a tacit, only assumed justification for learning objects (e.g., in lesson planning) without assessing learners' perceived relevance and referring to theoretical relevance frameworks (Stuckey et al., 2013). Different researchers of science education conceptualized relevance also by dividing it into dimensions (Van Aalsvoort, 2004; Stuckey et al., 2013). Such dimensions are (1) spatial relevance with the subdimensions: local, national, and global (see Sadler, 2004; Chowdhury et al., 2020), (2) social relevance with the subdimensions: individual, societal, and professional (Van Aalsvoort, 2004; Stuckey et al., 2013; Levrini et al., 2021), and (3) temporal relevance with the subdimensions: past, current, and future relevance (Stuckey et al., 2013; Levrini et al., 2021). The latter is not a focus of the present study.

In addition to the social, and temporal dimensions, Stuckey et al. (2013) propose another dimension, covering intrinsic and extrinsic relevance.

- The intrinsic subdimension comprises learners' perceptions based on their experiences, knowledge, interests, motives, values, and perspectives (Stuckey et al., 2013; Priniski et al., 2018). It also involves learners' perceived meaningfulness and usefulness of an object (Holbrook, 2008), aligning with the understanding of perceived relevance from motivation theory (Priniski et al., 2018).
- The extrinsic subdimension refers to the "real" relevance of an object stated by normative guidelines (e.g., curricula), society, science, and the learners' personal and social environment (Holbrook, 2008; Stuckey et al., 2013).

Stuckey et al. (2013) argue that relevance in science education should not only align with extrinsic aspects, it should also encompass learners' perceived, intrinsic relevance. PST' intrinsic relevance perceptions may differ from the extrinsic relevance, such as in the case of learning about SSI like OPM. The difference may arise because PST' intrinsic relevance perceptions are shaped by internal factors like interests and experiences, while extrinsic relevance is determined by external factors such as normative guidelines, curricular and societal requirements, and perspectives of other stakeholders (Stuckey et al., 2013), e.g., the oil palm lobby.

The current empirical study focuses on the intrinsic relevance of PST perceived spatial and social relevance dimensions. Thus, in the following the terms "perceived relevance" and "relevance perception" of PST always refer to the intrinsic subdimension.

2.2 Spatial relevance regarding socioscientific issue education

Spatial relevance can come into play, when dealing with environmental SSI such as deforestation and overfertilization (e.g., Duan and Fortner, 2005; Tuncay et al., 2012). Environmental SSI are relevant at different spatial scales, but often in different ways and to different degrees (Sadler, 2004; Wiyarsi et al., 2023). This usually results in the classification of local, national, and global SSI (Chowdhury et al., 2020; Wiyarsi et al., 2023). Existing studies of science and environmental education have investigated PST and college students' perceptions of environmental issues differently regarding spatial scales. In particular, they compared perceptions with respect to different constructs, e.g., experiences, knowledge, beliefs, concerns, and problem-solving. Next, we present diverging findings of four important studies in the field from four different countries on perceptions of local, national, and global environmental issues. However, these studies did not directly address relevance dimensions and subdimensions.

(1) Duan and Fortner (2005) showed for a number of so-called issue characteristics (e.g., tangibility, personal knowledge, impact on personal life) across eight local and nine global environmental issues that Chinese college students related more to local/national (e.g., air pollution in industrial cities) than to global issues (e.g., ozone depletion).
(2) In the study by Wiyarsi et al. (2023) on "scientific habits of mind," local and national SSI compared to global SSI tended to be more tangible for Indonesian PST. In this regard, personal experiences, cultural roots, local wisdom, and traditional knowledge seemed to play an important role in perceptions of SSI (Wiyarsi et al., 2023).
(3) In the study by Yli-Panula et al. (2023), Finnish PST perceived their influence on dealing with local environmental issues as stronger than with global issues, probably because these issues were closer to the lives of PST. They argued that PST might see their impact as future teachers higher at the local than at the global level.
(4) The study by Mahler (2020) with US college students found that perceived importance and concerns were higher for global issues than for local issues (e.g., deforestation of tropical vs. local old growth forests). However, college students' perceptions of local and global issues converged more during the semester course and their perceptions were more aligned with the scientific knowledge provided in the course (Mahler, 2020).

These studies highlight the importance of considering spatial subdimensions in SSI education as perceptions can vary for environmental SSI at the local, national, and global scales.

The PISA 2015 and PISA 2025 frameworks recognize the importance of using both local/national and global issues as contexts for assessing students' scientific literacy (OECD, 2023). The PISA frameworks specifically state that the selection of such contexts should consider the issues' relevance to students' lives (OECD, 2023). In other words, the frameworks acknowledge that using issues relevant to students at different spatial scales (local, national, global) is important for meaningful learning, and assessment of scientific literacy. However, there appears to be no explicit term for such spatial relevance. Thus, for us, perceived spatial relevance is the meaningful connection between a person and an object referring to local, national, and global scales. We understand the subdimensions of spatial relevance perceptions of learning about SSI as follows:

- Local relevance refers to learners' relevance of learning about SSI regarding the local community, region, and surrounding environment.
- National relevance refers to the national level, e.g., with relation to national politics, economics, and laws.
- Global relevance upscales the national relevance to the relevance for learning about SSI and their impact on the entire planet. It refers to learners' perceived relevance for learning about SSI concerning the world beyond the perceived relevance concerning one country.

Explicitly considering spatial relevance by addressing the perceived relevance of learning about SSI at local, national, and global scales can benefit learners, including PST. Recognizing the importance of local, national, and global relevance can promote education toward informed, responsible, and active citizens at all scales (Chowdhury et al., 2020). Knowledge about spatial relevance perceptions allows PST to design and implement SSI lessons more reflectively (Amos and Levinson, 2019).

2.3 Social relevance regarding socioscientific issue education

Regarding social relevance, Stuckey et al. (2013) established a framework model. It comprises social relevance with the subdimensions: individual, societal, and vocational relevance. This relevance model is particularly suitable for SSI education, as SSI education addresses the intersection of science and society (Stuckey et al., 2013; Nida et al., 2021).

Next, we elaborate on the social dimension with its subdimensions, referring to Stuckey et al. (2013). Instead of vocational relevance, we employ the term professional[1] relevance focusing on PST' relevance perceptions.

- Individual relevance refers to learners' perceived relevance for their own current and future lives and their individual identity. This can include all aspects and challenges in their personal environment and everyday life, but also personal needs, values, and beliefs of the individual.
- Societal relevance refers to the meaningful connection between the SSI and learners' sense of belonging to a group, such as their community or broader society (collective identity). It comprises a meaningful connection of learners with the interrelatedness of science and society. It also includes engaging with societal issues, and recognizing the current and future role of learners as citizens within a community and society.
- Professional relevance signifies the perceived relevance of learning about SSI for career-related choices, for professional qualification, and professional identity of learners. For PST, this perceived relevance usually pertains to their future role as educators. Profession-related relevance differs from the perceived relevance of all profession-unrelated areas of life, i.e., the private (everyday) life.

It is widely accepted that considering social relevance is crucial for SSI education (Hancock et al., 2019; Friedrichsen et al., 2021). However, the number of studies on social subdimensions for SSI education is limited. Furthermore, science teachers find it difficult to take or do not take at all social aspects of SSI into account (Friedrichsen et al., 2021). Hancock et al. (2019) investigated how US teacher teams considered relevance in selecting SSI (e.g., for food additives or invasive species). They found that the teams considered the individual relevance of SSI for learners, but less the societal and not the professional relevance in SSI education. In contrast, after participating in an educational unit on biodiesel, Indonesian PST perceived higher societal than individual relevance (Nida et al., 2021). Addressing the subdimensions individual, societal, and professional relevance in SSI education might provide valuable, differentiated insights for PST with respect to social relevance of teaching and learning about the complex interplay between science and society.

2.4 Locality of socioscientific issues as group difference regarding spatial and social relevance

For a comprehensive approach to SSI education, it is recommended that PST engage with real-world SSI that encompass local, national, and global aspects (Tuncay et al., 2012). Many environmental SSI depend on location conditions (e.g., climate, soil) and are situated in local contexts. Examples of such SSI, like oil palm or vanilla management, often comprise local, national, and global aspects and impacts (e.g., Grass et al., 2020; Wurz et al., 2022). A learner might perceive the relevance of learning about such SSI on the local, national, and global scale differently (spatial relevance). Moreover, the degree of perceived relevance at each scale may also depend on the specific locality of SSI in relation to learners' living, study place, or work region.

- Locality refers here to the particular region, where a SSI directly impacts the local scale. It can be categorized as either local or nonlocal to learners' place of residence, education (e.g., school and university), or work (Tuncay et al., 2012). Thus, the locality of SSI can determine groups of learners, which we refer to as local and nonlocal PST in this study.

Tuncay et al. (2012) found in a study with Turkish PST that locality of an environmental issue had no effect on moral reasoning across four local issues and four global issues on the same dilemma (e.g., deforestation in Turkey vs. deforestation of Amazon rainforest). Even if locality of the issue does not seem to affect moral reasoning regarding SSI by PST (Tuncay et al., 2012), the relevance of learning about SSI can be perceived differently by local and nonlocal PST (Sadler, 2004; Yli-Panula et al., 2023). For example, local PST studying in regions directly impacted by OPM may perceive the issue, e.g., because of their prior experiences, as much more locally relevant and connected to their lives than

1 For "vocational relevance," we follow the terminology by Van Aalsvoort (2004, p. 1152). It better suits PST as investigated group in our study.

nonlocal PST without any direct local impacts of the issue. If an issue is nonlocal to PST, PST might perceive more national and global relevance (Nida et al., 2021). However, nonlocal PST might perceive greater local relevance as they gain new knowledge about the local impact of the issue (see Mahler, 2020).

Currently, the extent to which the perceived spatial and social dimensions and locality of SSI influence local and nonlocal PST' relevance perceptions of learning about SSI remains largely unknown.

TABLE 1 Influencing factors for relevance of learning about socioscientific issues (SSI) perceived by pre-service teachers (PST).

Factors	Relevance subdimensions for learning about SSI	Locality of SSI as group difference for learning about SSI
Spatial (qualitative measures)	- Local - National - Global	- Local or nonlocal to PST' university → local or nonlocal PST
Social (quantitative and qualitative measures)	- Individual - Societal - Professional	

2.5 Expectancy-value theory: utility value as a construct of relevance

In the motivation theory of educational psychology, there are different approaches to conceptualize and measure perceived relevance stemming from different theoretical frameworks (Priniski et al., 2018). One of these is the expectancy-value theory (Wigfield and Eccles, 2000). The expectancy-value theory proposes the following: A person's behavior, e.g., choices, persistence, and performance can be explained by the person's expectations and beliefs. The expectations and beliefs are about how well the person will do in an activity and how they value it (Wigfield and Eccles, 2000). Applied to the educational context, the theory suggests that learners are more motivated to learn when they perceive the learning tasks as relevant and valuable to their lives (Wigfield and Eccles, 2000; Priniski et al., 2018).

From the expectancy-value theory derives the utility value. It stands for the perceived usefulness of learning about objects for current and future goals (Hecht et al., 2021). Thereby, utility value refers more to the usefulness of a task for specific goals of a person than to how it affects interest, competence, and achievements directly (Priniski et al., 2018). Still, perceiving utility value can foster interest development, performance, and influence personal identification (Priniski et al., 2018; Hecht et al., 2021). Thus, the goal-orientation distinguishes the more specific utility value perception from the more general relevance perception of an object for a person.

One established way for utility value promotion is the so-called utility value intervention. It consists of activities that stimulate students to reflect upon the usefulness of learning objects for their lives (Priniski et al., 2018; Hulleman and Harackiewicz, 2021). The utility value intervention was developed "to increase students' perceptions of the relevance of academics to their lives" (Hulleman et al., 2016, p. 265). Besides explanations by educators about the utility value of the learning object, it can be beneficial to provide opportunities for learners to recognize the utility value themselves. One way is, e.g., through written, so-called self-generated, utility value reflections (Hecht et al., 2021; Hulleman and Harackiewicz, 2021). Prompting such reflections by a writing task can be an effective approach for assessing relevance perceptions in short timeframes (Hecht et al., 2021).

Analogous to the subdimensions of social relevance perceptions in science education, studies examine subdimensions of "social" utility value perceptions but not in SSI contexts: individual (Gaspard et al., 2015b; Hecht et al., 2021), individual and societal (Beigman Klebanov et al., 2017), and individual and professional utility value (Gaspard et al., 2015b; Wang and Lewis, 2022). Gaspard et al. (2015b) found that utility value perceptions can be empirically differentiated with respect to various areas of life such as everyday and future, personal and social life, as well as education and profession. Thus, adapting utility value research for SSI education might be a promising approach for addressing PST' perceptions of the social but also of the spatial relevance dimension of learning about SSI.

2.6 Oil palm management—A suitable socioscientific issue to expand research on spatial and social relevance perceived by local and nonlocal pre-service teachers

Relevance perceptions, e.g., regarding the spatial and the social dimensions, are not independent. They can be intertwined (Stuckey et al., 2013). For example, learners may perceive learning about plastic pollution in rivers as locally and individually as well as globally and societally relevant. However, very few studies have simultaneously addressed the spatial and social relevance or utility value of learning about SSI. The PISA frameworks address both dimensions: the local and national ("community"), and global ("life across the world") aspects referring to the spatial dimension and the personal ("self, family, and peer groups") aspects of the social dimension. These aspects make up a key criterion for science-related issues to address (OECD, 2023). Also, Amos and Levinson (2019) and Chowdhury et al. (2020) emphasize the close links between perspectives—such as personal, social, local, and global—connected to the spatial and social dimensions and the perspective importance for learning about SSI. The study by Yli-Panula et al. (2023) showed spatial effects of SSI on PST' perceived impact as future educators. Their findings indicate a relationship between PST' perceived spatial relevance, professional relevance, and locality of the SSI. Furthermore, teaching and learning about local SSI seem to promote individual relevance more in comparison to global SSI (Sadler, 2004). If educators want global SSI to be as meaningful as local SSI, they might be required to additionally support learners (e.g., with scaffolds) for developing personal connection of the learners to the SSI (Sadler, 2004; Duan and Fortner, 2005). Spatial and social relevance perceptions and the locality of the SSI for PST (Table 1) appear to be interrelated. However, how and to what extent these factors influence the perceived relevance of learning about SSI still remains

an open question. An example for one SSI with spatial and social components is conventional OPM in Jambi province, Indonesia (Nida et al., 2021). This complex SSI affects socioeconomic and environmental aspects of (un)sustainable development. Examples are local jobs and health, national economy, global consumption, biodiversity, and climate change (Grass et al., 2020; Iddris et al., 2023). Currently, Indonesia is the country with the highest palm oil production and therefore much land is used (see Iddris et al., 2023). Palm oil is a part of everyday life (e.g., food, cosmetics, fuel). Thus, learning about OPM is extrinsically relevant and may be perceived as intrinsically relevant to PST' lives (Nida et al., 2021). OPM appears to be a suitable SSI to investigate spatial and social relevance perceptions in a differentiated way by considering the local, national, and global subdimensions as well as the individual, societal, and professional subdimensions. Furthermore, there are positively evaluated educational units on oil palm issues (Nida et al., 2021; Matthiesen and Bögeholz, 2024). One of the units is a 5-week educational unit on OPM as SSI embedded in curricular courses of teacher education at Indonesian universities (Matthiesen and Bögeholz, 2024). The unit has been designed and evaluated by an international project team and published in an open book (Matthiesen and Bögeholz, 2024).

3 Research questions addressing the spatial and social relevance of learning about oil palm management as socioscientific issue

A differentiated analysis of spatial and social relevance dimensions can provide knowledge to make recommendations to teacher educators and curriculum designers on how to support and prepare PST for their future profession with respect to relevance perceptions. However, science education research often relates to general relevance. While some studies on environmental issues have examined the spatial effects of issues on students' knowledge, beliefs, and concerns, they have not explicitly investigated PST' spatial relevance perceptions of learning about SSI or how these perceptions depend on the locality of the SSI. Social relevance subdimensions such as societal and professional relevance are partly neglected (Stuckey et al., 2013; Hancock et al., 2019). In addition, educators often insufficiently address social subdimensions in SSI education (Friedrichsen et al., 2021). Thus, there is a research gap regarding spatial and social relevance (subdimensions) of learning about SSI perceived by local and nonlocal PST.

We aim to bridge this gap by simultaneously investigating both, spatial (local, national, global) and social (individual, societal, professional), relevance perceptions of learning about OPM as SSI. Furthermore, we want to find out how the locality of OPM for PST interacts with the spatial and social subdimensions for the perceived relevance of learning about OPM.

It is important to note that we target PST' subjective, intrinsic relevance perceptions of learning about OPM, employing a utility value mixed-methods approach (see Section 4). To explore intrinsic relevance perceptions, we investigate how the locality of OPM influences PST' perceived spatial and social relevance of learning about OPM.

We expect that the educational unit on OPM, which includes relevance reflections, can promote different subdimensions of PST' perceived relevance over time. For local PST, learning about OPM should be of high local as well as individual and professional relevance (cf. Sadler, 2004; Yli-Panula et al., 2023). We expect nonlocal PST to refer more to the relevance on the national and global scales and perceive higher societal relevance of learning about OPM (Nida et al., 2021). Through learning about OPM, nonlocal PST in comparison to local PST, should have a greater increase of perceived relevance after the unit. Presumably, they have fewer personal experiences, more knowledge gaps and consequently can gain more new knowledge about the SSI (cf. Mahler, 2020). In the present study, we investigate two research questions (RQ), each comprising three hypotheses (H):

RQ1: To what extent does the locality of oil palm management (OPM) influence PST' relevance perceptions of learning about OPM (a) overall, (b) through the educational unit over time, and (c) regarding relevance reflections referring to spatial subdimensions?

- H1a: Local PST perceive a higher relevance of learning about OPM than nonlocal PST.
- H1b: The perceived relevance of learning about OPM increases for all PST but converges through the unit over time between local and nonlocal PST.
- H1c: Local PST refer in their relevance reflections on learning about OPM more to the local subdimension, while nonlocal PST refer more to the national and global subdimensions.

RQ2: To what extent does the locality of OPM influence PST' relevance perceptions of learning about OPM regarding (a) the social subdimensions, (b) social subdimensions through the unit over time, and (c) relevance reflections referring to social subdimensions?

- H2a: Local PST perceive a higher individual and professional relevance of learning about OPM than nonlocal PST.
- H2b: Nonlocal PST have a greater increase for all social relevance subdimensions of learning about OPM through the unit over time in comparison to local PST.
- H2c: Local PST refer more to themselves as individuals and their future profession in their relevance reflections, whereas nonlocal PST refer more to society.

4 Materials and methods

In the current study, we followed a mixed-methods evaluation approach with an educational unit on OPM (Figure 1). The following sections outline the participants and sample sizes, describe the structure of the educational unit, and detail the quantitative and qualitative measures alongside their respective analyses.

4.1 Participants

The sample consisted of 111 PST (88% female) in their second or third study year. This implies that PST

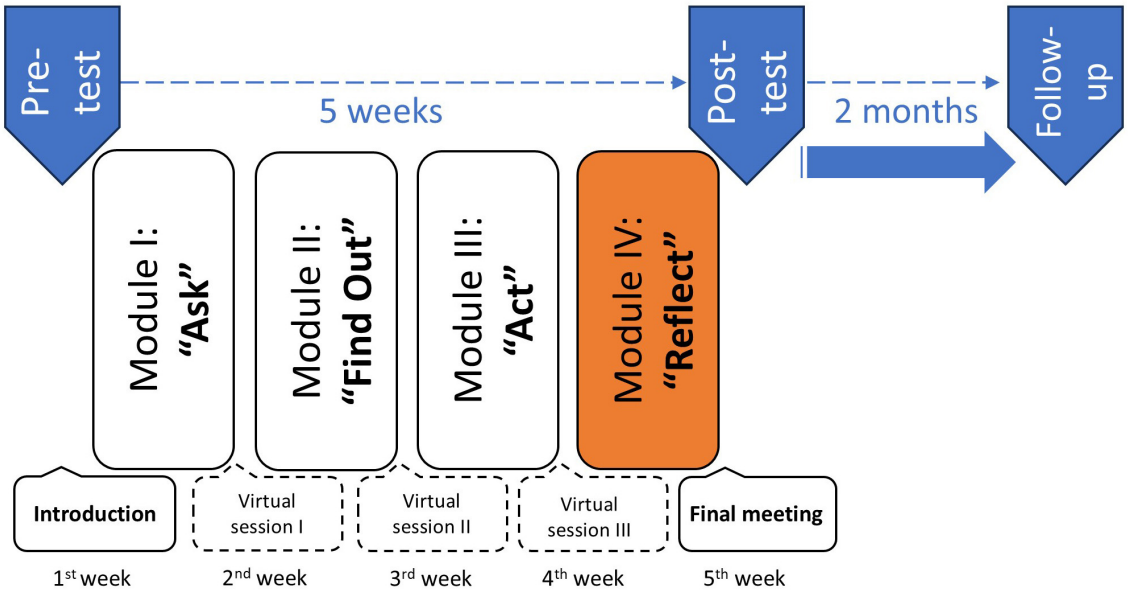

FIGURE 1
Educational unit on oil palm management and study procedure. The unit comprises four modules with accompanying virtual sessions (represented as text bubbles). In the fourth module, a qualitative assessment (orange) is integrated into teaching and learning. The quantitative assessment follows a pretest-posttest-follow-up design.

were, on average, between 19 and 21 years old (based on verbal communication with lecturers). The PST studied at three different public universities on three Indonesian islands.

Local PST: 51 PST were enrolled at a university located in a region on Sumatra with OPM as local SSI. They belonged to two study programs:

- 38 PST of biology education who participated in a plant physiology course.
- 13 PST of chemistry education who participated in an organic chemistry course.

Nonlocal PST: 58 PST studied in regions without OPM as local SSI.

- 47 PST were enrolled in the science education study program participating in an ecology course at one university in East Java.
- 11 PST of the biology education study program from the third university, which was situated on Bali, took part in a horticulture course.

All participants were retained for data analysis. However, due to missing university information (two participants), incomplete data, or unmet utility value criteria (see below and Supplementary Data Sheet), the sample sizes for statistical analyses were reduced as follows: $n_{qn\_social} = 108$ (50 local/58 nonlocal), $n_{ql\_spatial} = 101$ (43 local/58 nonlocal), and $n_{ql\_social} = 109$ (51 local/58 nonlocal) (qn = quantitative; ql = qualitative).

4.2 Educational unit on oil palm management

The overall objective of the educational unit was to engage students with OPM as SSI and with science-based management strategies, concerning weeding and fertilizing, toward the sustainable development goals. The content of the unit was primarily based on research contexts, methods, and findings as well as media mainly of the Oil Palm Management Experiment of the Collaborative Research Center: "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems (Sumatra, Indonesia)" (2012–2023). The 5-week educational unit on OPM was embedded in curricular courses of the participating universities.

The OPM unit is a self-learning unit based on socioscientific inquiry-based teaching and learning approaches (Sadler et al., 2017; Amos and Levinson, 2019). It had a modular design (Figure 1): In the first module, PST encountered the environmental, socioeconomic, and societal impacts of conventional OPM on the local, national, and global scale and formulated research-informed questions ("Ask"). In the second module ("Find Out") and third module ("Act"), PST engaged with cutting-edge research on OPM practices with respect to more sustainable weeding and fertilizing. At the end of the third module, PST were asked to compile and finalize an infographic on what they have learned so far on OPM. Overall, the infographic design and presentation served as overarching activity for the whole unit. In the last module (IV; "Reflect"), PST reflected on the relevance of learning about OPM. Across the modules, PST practiced scientific inquiry, dealing with complexity, perspective-taking, scientific and socioscientific

reasoning and sceptism (Sadler et al., 2017; Amos and Levinson, 2019). More details on the self-learning modules "Ask," "Find Out," and "Act" are published in Matthiesen and Bögeholz (2024). Students received a certificate for their full participation in the study.

4.3 Mixed-methods approach for measuring perceived utility value

We adapted established quantitative and qualitative utility value measurements to learning with our SSI content. The aim of our mixed-method approach was to assess the perceived subdimensions of relevance regarding learning about OPM. We proceeded as follows[2]:

- Quantitatively, we conducted online utility value surveys with a pretest-posttest-follow-up design (Figure 1), adapting utility value items from Hecht et al. (2021, Table 2). The adapted utility value survey was pretested and optimized based on lecturers' and PST' feedback in a pilot study.
- Qualitatively, we measured self-generated utility value through a two-part writing reflection task stimulated by utility value writing prompts (Beigman Klebanov et al., 2017; Hecht et al., 2021; Hulleman and Harackiewicz, 2021) and group discussions in module IV.

Triangulating quantitative and qualitative findings strengthens the credibility, trustworthiness, and validity of conclusions about PST' utility value perceptions (Creswell and Plano Clark, 2017). The pretest-posttest-follow-up (repeated-measures) design and integration into an actual teacher education course can enhance ecological validity (Liebendörfer and Schukajlow, 2020). For both quantitative and qualitative measurements, the locality of OPM for the PST was used as factor, which determined two groups: local and nonlocal PST (Table 1).

The educational unit and all quantitative and qualitative measurements were available in English and Indonesian during the study.

4.3.1 Quantitative measures

With the scale of adapted items for perceived utility value (Hecht et al., 2021, Study 1), we measured the social subdimensions of the perceived utility value as relevance construct (Table 2). We used online questionnaires at three measurement points (Figure 1): pretest, posttest (at the end of the unit, 5 weeks after pretest), and follow-up (2 months after posttest). The adaptations aligned the items with learning about OPM, instructional contexts, the social subdimensions of relevance, and the appropriate language and format for the Indonesian version of the survey. Each "social" utility value subdimension was nested into four instructional contexts of learning about OPM: *oil palm management*, *crop cultivation*, *scientific research*, and *sustainable development*. We changed the 7-point to a 5-point Likert-scale (Table 2) as the PST were more familiar with this scale according to Indonesian lecturers and study program coordinators. Cronbach's alpha values for the social subdimensions ranged between 0.80 and 0.92, indicating high internal consistency.

4.3.2 Qualitative measures

The purpose of the qualitative measure was to assess PST' self-generated utility value perceptions of learning about OPM and to analyze their responses with respect to the social and spatial dimensions (see Section 4.4). The qualitative measure in module IV "Reflect" consisted of a two-part utility value writing reflection task with an embedded group discussion. For both task parts, we changed the "standard" utility value prompt (Hecht et al., 2021; Hulleman and Harackiewicz, 2021) to align it with survey items on utility value, the content of the educational unit, and with suitable wording and format for Indonesian PST.

First, PST were asked to respond to a utility value question by a given 15-min online writing prompt (task part 1): "In which way can what you learned in the unit (on how weeding and fertilizing can contribute to sustainable oil palm management) be useful to you? Elaborate on how the information of the unit can be useful to you in your life. Please give examples. Please write 2–3 paragraphs."

Then, the PST worked in a discussion group of three to five people on three discussion stimuli for 45 min. The utility value stimuli comprised peer quotes (Gaspard et al., 2015a), short information texts, and questions (Soicher and Becker-Blease, 2023) for reflections (see Supplementary material S1). These content-related stimuli aimed to bring social subdimensions into the discussions. The underlying goal was to promote transferability in making use of gained knowledge of learning about OPM for different groups of people (smallholders, farmers of other crops, and everyone) and for PST' future profession (Gaspard et al., 2015a; Harackiewicz et al., 2023).

Finally, based on the group discussions, PST were asked to individually respond to a second 10-min writing prompt with the same structure but a different question that expands the prompt to address utility value for other societal groups. The question of task part 2 explicitly addressed different social perspectives: "In which way can what you have learned in the unit be useful to (a) you, (b) others, and (c) everyone?".

The modules "Ask," "Find Out," and "Act" of the OPM unit did not include any directly communicated utility value stimulus, i.e., explicit explanations and examples of how learning about OPM is useful to the lives of the PST (Hecht et al., 2021).

4.4 Coding of responses to utility value reflection task

To analyze PST' responses to the utility value writing task with respect to relevance subdimensions, we followed a systematic coding procedure oriented to qualitative content analysis (Mayring, 2014). To fulfill the criteria to be a utility value response, responses were required to be personal (first-person pronouns), specific, and content-relevant (Hulleman and Harackiewicz, 2021). We determined three categories for the utility value coding:

The first category represented the spatial utility value dimension:

2 With the permission of Judith Harackiewicz' research group.

TABLE 2 Items representing the subdimensions for the perceived social utility value (based on Hecht et al., 2021), *[nested instructional contexts of learning about oil palm management]*, related social relevance subdimensions, and Cronbach's alpha ($n_{qn\_social} = 108$).

Items for perceived social utility value	Social relevance subdimensions	Cronbach's alpha		
		Pretest	Posttest	Follow-up
i. I think understanding about *[1–4]* will be useful to me	Individual	0.89	0.87	0.92
ii. I think understanding *[1–4]* is relevant to my life	Individual	0.83	0.80	0.90
iii. I think knowing about *[1–4]* is useful in my future profession	Professional	0.84	0.88	0.92
iv. I think *[1–4]* is important for everyone to understand	Societal	0.92	0.86	0.92

Item agreement was measured on a 5-point Likert-scale: 0 (disagree), 1 (slightly agree), 2 (mostly agree), 3 (agree), and 4 (strongly agree).
Nested instructional contexts: [1] oil palm management, [2] crop cultivation, [3] sustainable development, [4] scientific research.

- For spatial references, we distinguished between the codes "local," "national," and "global" in utility value task responses, which included at least one coded pronoun.

The second and third categories, oriented to Beigman Klebanov et al. (2017), represented the social subdimensions. The social categories were:

- Pronouns with the codes "I" (singular pronouns comprising me, my, myself) indicating individual utility value (individual identity), and "We" (plural pronouns comprising us, our, ourselves etc. and related terms e.g., all, everyone, community, and society) indicating societal utility value (collective identity).
- Profession with the codes "profession-unrelated" and "profession-related" to PST' future profession as educators coded for each utility value pronoun reference.

The coding procedure comprised three steps. The coders

(1) Checked if the responses fulfilled the utility value criteria and coded the used pronouns in the utility value responses.
(2) Analyzed whether each reference with a pronoun code was related or unrelated to PST' future profession as educators and coded accordingly. Thus, the codes "profession-unrelated" and "profession-related" were nested into the pronoun codes "I" and "We."
(3) Coded spatial references in responses, which fulfilled the utility value criteria.

Multiple codes from one category (e.g., *"I"* and *"We"* in one response) or more categories (e.g., *"I" unrelated to profession*, *"We" related to future profession*, and reference to the *national* scale in one response) could be assigned to a single response. For coding examples of responses to the utility value writing task for each category, see Supplementary Table S2.

Three coders with prior experience in qualitative content analysis applied the coding procedure to pilot study data (25 responses) as training. They discussed difficulties and uncertainties and refined the coding manual.

After the training, the coders analyzed and coded full responses by the PST of the current study to the utility value task (combined task parts 1 and 2; $n_{qn\_social} = 109$). First, three coders analyzed 27 (25%) responses with "almost perfect" inter-coder agreement of $\kappa = 0.86$ (Fleiss's kappa, Landis and Koch, 1977). After that, they improved and refined the categories again. Then, the three coders analyzed all responses (100%) with an "almost perfect" agreement of $\kappa = 0.83$. Final codes were determined by consensus-building discussions between the three coders in cases of disagreement. Eight of the submitted responses (7%) did not fulfill the utility value criteria and were without utility value references in any category.

4.5 Statistical data analyses of utility value data

Statistical analyses of both, the surveyed quantitative data and the codes derived from the content analysis of qualitative PST' responses to the utility value task, were performed using (generalized) linear mixed-effect models (type II sums of squares).

4.5.1 Quantitative data analysis

We analyzed the quantitative data with a full-factorial linear mixed-effect model. Perceived utility value of learning about OPM served as response variable. The model included time measurement points (pretest, posttest, follow-up), social subdimensions of utility value (Table 2), and the locality of OPM (local or nonlocal for PST) and their interactions as fixed effects. The random effect structure comprised intercepts for the subject identification number (ID) and random slopes for the interaction of ID and time. Gender and course as factors affected PST' utility value of learning about OPM. However, to reduce model complexity, we did not include gender and course as fixed factors in the final models, as they did not qualitatively affect the results (Supplementary Data Sheet). Testing assumptions of our model revealed that the residuals were non-normally distributed. However, violating this model assumption does not seem to affect outcomes of linear mixed-effect models with Likert-scales (Norman, 2010; Schielzeth et al., 2020).

4.5.2 Qualitative data analysis

For the analysis of the qualitative data, we used two generalized linear mixed-effect models—one "spatial" (ad RQ1) and one "social" (ad RQ2)—with a binomial error distribution and a logit

link. For both models, we used the reference codes for PST' responses to the utility value task as a binary response variable (i.e., with or without reference). In the "spatial" model, we used the categorical factors spatial reference (local, national, and global), and the locality of OPM (local or nonlocal for PST) as fixed effects. We analyzed references to the social utility value in a separate model using the categorical factors pronoun ("I" and "We"), future profession (unrelated or related) nested in pronoun, and the locality of OPM (local or nonlocal for PST) as fixed effects. We used the ID of PST for both generalized linear mixed-effect models as random factor. The eight responses without any utility value references (see Section 4.4) reduced the ID number in the spatial model ($n_{ql\_spatial} = 101$) compared to the social model ($n_{ql\_social} = 109$).

The R program version 4.3.2 was used for all statistical analyses (R Core Team, 2023). The R-package "glmmTMB" version 1.1.7 was applied to construct (generalized) linear mixed models (Brooks et al., 2017). We performed Wald-χ^2 tests in the R-package "car" version 3.1–2 to determine significance values (Fox and Weisberg, 2018). The R-package "DHARMa" version 0.4.6 allowed us to assess each model's performance (Hartig, 2022). Results are reported as estimated marginal means with confidence intervals (CI).

5 Results

In the following sections, we present our study results on spatial and social relevance perceptions of PST as well as on locality effects of SSI on PST' perceived relevance of learning about OPM in a differentiated way. Sections 5.1 and 5.2 present the results for RQ1 and RQ2, respectively, starting with an overview of the main findings, followed by detailed results.

5.1 Locality, time, and spatial effects on the utility value of learning about oil palm management—Ad RQ1

The OPM educational unit influenced PST' perceived utility value of learning about OPM over time (Table 3). Nonlocal PST perceived higher utility value of learning about OPM than local PST. This is in contrary to H1a, claiming local PST would perceive higher relevance than nonlocal PST. Moreover, the results do not support H1b, as there was no interaction effect of locality of OPM and time (Table 3, Figure 2).

Local, national, and global references in their responses to the writing task differed among PST (Table 4, Figure 3). Local PST referred more to the local relevance subdimension, while nonlocal PST referred more to the national relevance subdimension. The probability of utility value references with respect to the global subdimension did not differ between local and nonlocal PST. Thus, H1c, could be confirmed, except for the global relevance subdimension.

5.1.1 Results regarding the quantitative data—Ad RQ1

The average perceived utility value of learning about OPM, estimated as the fixed intercept in the model and reported as

TABLE 3 Mixed-model analyses of variance of the effects of time (pretest, posttest, and follow-up), social subdimensions (useful to me, relevant to my life, useful in my future profession, and important for everyone to understand; see Table 2), and locality of oil palm management for pre-service teachers (local or nonlocal PST) on the perceived utility value of learning about oil palm management ($n_{qn\_social} = 108$).

Factors	df	Wald-χ^2	p
Locality	1	11.165	<0.001
Time	2	17.101	<0.001
Locality × time	2	0.462	0.794
Social subdimensions	3	144.458	<0.001
Social subdimensions × time	6	17.514	0.008
Social subdimensions × locality	3	9.486	0.023
Social subdimensions × locality × time	6	8.889	0.180

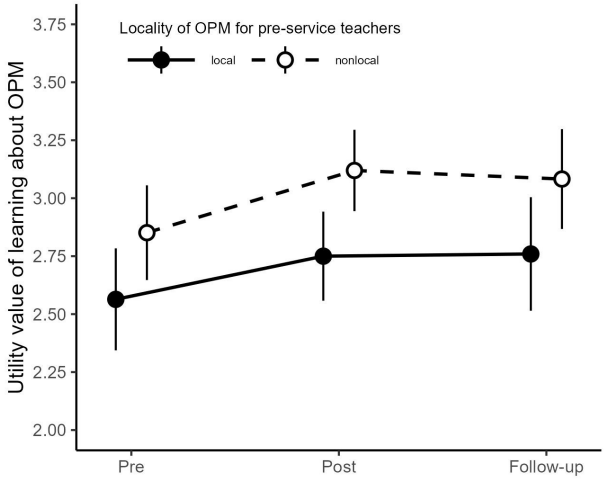

FIGURE 2
The effect of the 5-week educational unit over time (follow-up: 2 months after post) and the effect of locality of oil palm management (OPM) for pre-service teachers on the perceived utility value of learning about OPM ($n_{qn\_social} = 108$). The Likert-scale ranged from 0 (disagree) to 4 (strongly agree). Error bars indicate 95% confidence intervals.

TABLE 4 Generalized mixed-model analyses of variance of the effects of the spatial relevance subdimensions (local, national, and global) and locality of oil palm management for pre-service teachers (local or nonlocal) on the probability for utility value references in a writing task response ($n_{ql\_spatial} = 101$).

Factors	df	Wald-χ^2	p
Spatial subdimensions	2	8.333	0.016
Locality	1	0.001	0.978
Spatial subdimensions × locality	2	19.959	<0.001

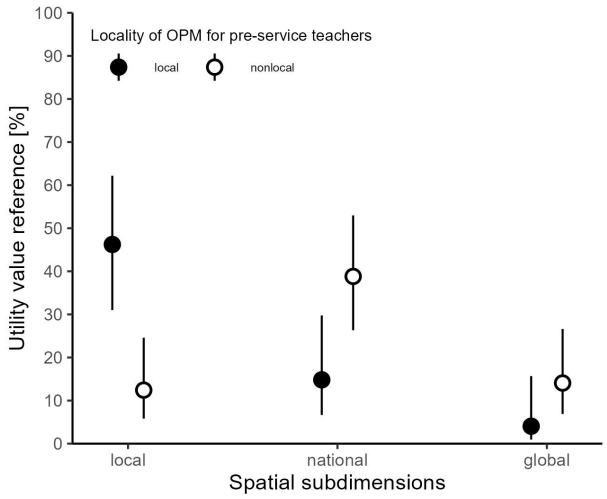

FIGURE 3
Probability of utility value reference in writing task responses for the spatial relevance subdimensions (local, national, and global), separated for the locality of oil palm management (OPM) for pre-service teachers ($n_{ql\_spatial} = 101$). Error bars indicate 95% confidence intervals.

estimated marginal mean, was 2.76 [95% CI (2.54, 2.98)]. Nonlocal PST perceived the utility value of learning about OPM higher than local PST across time measurement points [locality main effect: 3.02 (2.82, 3.22) vs. 2.69 (2.47, 2.91)]. Regardless of the locality of OPM, PST' perceived utility value increased over time [time main effect: pre: 2.71 (2.50, 2.92), post: 2.93 (2.75, 3.12), follow-up: 2.92 (2.69, 3.15)].

5.1.2 Results regarding the qualitative data—Ad RQ1

References to the spatial subdimensions—local, national, and global—in the utility value responses to the writing task differed among PST and between local and nonlocal PST (Table 4, Figure 3). Local PST referred more to the local subdimension, while nonlocal PST referred more to the national subdimension (Figure 3). Regarding the spatial main effect (Table 4), the probability of utility value references to the local subdimension [0.29 (0.18, 0.43)] and national subdimension [0.27 (0.17, 0.41)] did not differ, but their probabilities were higher than to the global subdimension [0.09 (0.04, 0.21)]. There was no locality main effect (Table 4).

5.2 Social main and interaction effects on the perceived utility value of learning about oil palm management—Ad RQ2

The social subdimensions—individual, societal, and professional—and their two-way interactions with time and with the locality of OPM for PST affected the quantitatively surveyed utility value of learning about OPM (Table 3). However, there was no three-way interaction of social subdimensions, time, and locality (Table 3). Nonlocal PST perceived the utility value of all social subdimensions higher in comparison to local PST (Figure 4). This is not in line with H2a, claiming that local PST would perceive higher individual and professional relevance than nonlocal PST.

Furthermore, the increase in perceived utility value over time for the professional and societal subdimensions was greater for nonlocal PST than for local PST. Thus, hypothesis H2b was supported, except for the individual subdimension (Figure 4).

In their responses to the writing task, used pronouns, relation to the future profession as educators or unrelation to profession, and the locality of OPM for PST affected the probability of utility value references (Table 5, Figure 5). Nonlocal PST had a higher probability of utility value references overall. They referred more to both pronouns ("I" and "We") and to their future profession than local PST. These results only partially support H2c, claiming that local PST would refer more to themselves as individuals and their future profession, while nonlocal PST would refer more to society.

5.2.1 Results regarding the quantitative data—Ad RQ2

The social utility value subdimensions differed among PST (main social subdimensions effect, Table 3): The utility value of

- "I think understanding about *[oil palm management, crop cultivation, sustainable development, and scientific research]* will be useful to me" [3.07 (2.86, 3.28)] was perceived higher than "I think *[. . .]* is important for everyone to understand" [2.89 (2.68, 3.10)].
- "I think understanding *[. . .]* is relevant to my life" [2.71 (2.50, 2.92)], and "I think knowing about *[. . .]* is useful in my future profession" [2.75 (2.54, 2.95)] were rated lowest in terms of utility value.

There was an interaction effect of the social subdimensions and time on the perceived utility value of learning about OPM (Table 3; see Figure 4). PST rated the utility value for the item "useful to me" above 3 (agree) at all three measurement points. Thus, the individual usefulness perceived by PST sustained over time. In contrast, "relevant to my life," which was the other item related to the individual subdimension (Table 2), increased from pretest to follow-up [pre: 2.54 (2.33, 2.75), post: 2.75 (2.57, 2.94), follow-up 2.85 (2.62, 3.08)], though it remained lower than "useful to me" at follow-up. The perceived utility value of learning about OPM among PST differed between "useful to me" and "relevant to my life" across all time measurement points as well as regardless of time.

The perceived utility value for "useful in my future profession" increased from pretest to posttest and from pretest to follow-up [pre: 2.54 (2.32, 2.75), post: 2.88 (2.70, 3.07), follow-up 2.82 (2.59, 3.05)], while the utility value for "important for everyone to understand" increased only from pretest to posttest [pre: 2.75 (2.53, 2.96), post: 3.01 (2.83, 3.20), follow-up 2.91 (2.68, 3.14)].

There was a two-way interaction between social subdimensions and locality on the perceived utility value of learning about OPM (Table 3). The perceived utility value for nonlocal PST

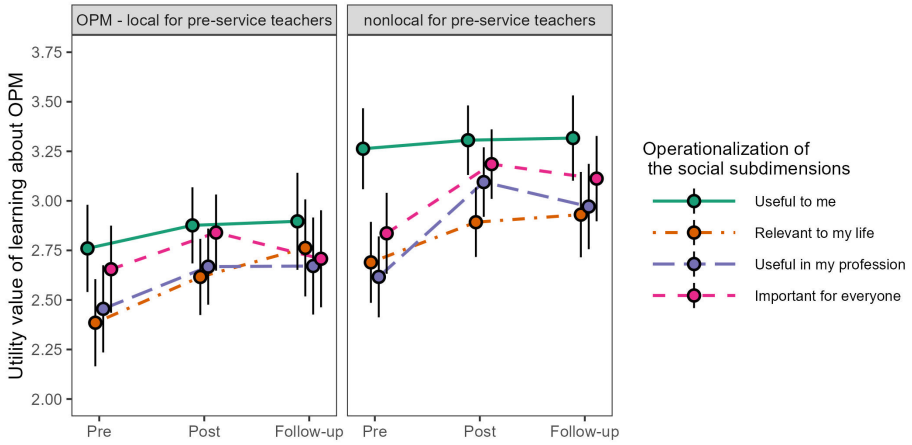

FIGURE 4
The effect of social subdimensions through the 5-week educational unit over time (follow-up: 2 months after post) on pre-service teachers' perceived utility value of learning about oil palm management (OPM; $n_{qn\_social} = 108$). Results are separated by the locality of oil palm management (OPM) for pre-service teachers (local or nonlocal). The operationalization of the social subdimensions (Table 2) comprises: "I think understanding about *[oil palm management, crop cultivation, sustainable development, and scientific research]* will be useful to me" and "I think understanding *[...]* is relevant to my life" (both individual relevance), "I think knowing about *[...]* is useful in my future profession" (professional relevance), and "I think *[...]* is important for everyone to understand" (societal relevance). The Likert-scale ranged from 0 (disagree) to 4 (strongly agree). Error bars indicate 95% confidence intervals.

compared to local PST of learning about OPM was higher for each social subdimension.

- Local and nonlocal PST rated the subdimension "useful to me" as highest [local: 2.84 (2.63, 3.06), nonlocal: 3.30 (3.10, 3.49)],
- Followed by "important for everyone to understand" as second highest [local: 2.73 (2.52, 2.95), nonlocal: 3.04 (2.85, 3.24)], and
- "Useful in my future profession" [local: 2.60 (2.38, 2.82), nonlocal: 2.89 (2.70, 3.09)] and
- "Relevant to my life" as lowest [local: 2.59 (2.37, 2.81), nonlocal: 2.84 (2.64, 3.04)].

There was no three-way interaction effect among social subdimensions, locality, and time (Table 3). Nevertheless, we want to note that the utility value perceived by nonlocal PST strongly increased from pretest to posttest regarding the societal subdimension "important for everyone to understand" and the professional subdimension "useful in my future profession" (Figure 4).

5.2.2 Results regarding the qualitative data—Ad RQ2

The statistical analysis of the qualitative data for RQ2 revealed main effects for used pronouns, (un)relation to the future profession, and locality of OPM for PST on the probability of utility value references (Table 5). For used pronouns in responses, the probability of utility value references for "I" [0.59 (0.48, 0.69)] was higher than for "We" [0.32 (0.24, 0.43)]. More responses with pronouns [0.72 (0.60, 0.81)] were unrelated to the profession of PST than related to their future profession as educators [0.19 (0.12, 0.31)]. The probability of utility value references was higher for nonlocal PST [0.58 (0.48, 0.67)] than for local PST [0.34 (0.24, 0.46)].

TABLE 5 Generalized mixed-model analyses of variance of the effects of used pronoun ("I," "We"), unrelated or related to future profession of utility value responses, and locality of oil palm management for pre-service teachers (local or nonlocal PST) on the probability of utility value references ($n_{ql\_social} = 109$).

Factors	df	Wald-χ^2	p
Pronoun	1	35.301	<0.001
Profession	1	79.364	<0.001
Locality	1	28.523	<0.001
Pronoun × profession	1	0.030	0.863
Pronoun × locality	1	1.679	0.195
Profession × locality	1	0.949	0.330
Pronoun × profession × locality	1	1.938	0.164

There were no two-way and three-way interaction effects of pronoun, profession, and locality (Table 5). It is noteworthy that while local PST' references to the future profession did not differ between "I" and "We," nonlocal PST showed higher probability of utility value references to the future profession for "I" than for "We" (Figure 5).

6 Discussion

The mixed-methods utility value approach, embedded within a 5-week curricular unit, gave us a comprehensive picture on PST' spatial and social relevance perceptions: We gained insights on how local and nonlocal PST made connections between learning

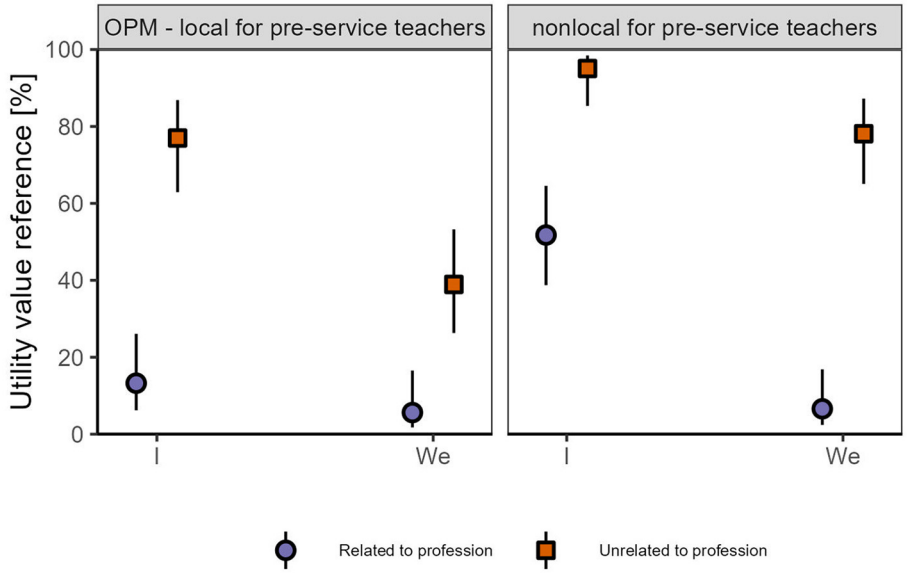

FIGURE 5
Probability of utility value reference in writing task responses for the pronouns "I" and "We" nested into unrelation or relation to future profession ($n_{ql\_social} = 109$), separated for the locality of oil palm management (OPM) for pre-service teachers (local or nonlocal). Error bars indicate 95% confidence intervals.

about OPM and their lives. While utility value is a specific construct originated from the expectancy-value theory, we use the term relevance in the following discussion to situate our findings in a broader context and to align it with the study's overarching aim of understanding relevance perceptions. We begin by discussing PST' perceived relevance over time, followed by elaboration on our results in relation to the research questions and hypotheses.

The educational unit, designed to promote science-based knowledge for PST on sustainable OPM (Matthiesen and Bögeholz, 2024), was positively evaluated regarding the instructional design prior to the study. However, the extent to which the unit fostered PST' relevance perceptions for learning about OPM remained unclear. In this regard, the following quantitative results are promising:

PST' perceived relevance of learning about OPM increased through the unit over time.

- From pretest to posttest over 5 weeks and sustained at the follow-up 2 months after (main time effect),
- For the professional subdimension from pretest to posttest and from pretest to follow-up, and
- For the individual subdimension regarding the item "relevant to my life" from pretest to follow-up.

Furthermore, the perceived relevance among PST was relatively high on average. These results suggest that educational units incorporating a relevance reflection and socioscientific inquiry-based learning can increase and sustain perceived relevance of learning about SSI for PST' lives and future profession as educators. Overall, our findings indicate that the utility value approach is suitable and efficient for measuring relevance perceptions of learning about SSI in a short timeframe (Hulleman et al., 2016; Priniski et al., 2018; Hecht et al., 2021).

6.1 Learning about oil palm management as socioscientific issue perceived as more relevant for nonlocal pre-service teachers?—Ad RQ1

The locality of OPM for PST affected their relevance perceptions of learning about OPM. Differently than expected,

- Local PST perceived the relevance of learning about OPM lower than nonlocal PST (contradicting H1a).
- Qualitatively, local PST also had a lower probability of relevance references in their responses to writing reflection task on learning about OPM.
- There was no interaction effect between locality and time on the perceived relevance of learning about OPM. The perceived relevance did not converge over time more between local and nonlocal PST. This indicates that the educational unit equally promoted perceptions of local and nonlocal PST with respect to the overall relevance of learning about OPM (contradicting H1b).
- Regarding the spatial relevance subdimensions, local PST referred in the reflection task responses more to the local subdimension, while nonlocal PST referred more to the national subdimension. However, there was no difference between local and nonlocal PST regarding references to the global subdimension (partially supporting H1c).

Our findings indicate that local and nonlocal PST perceive the relevance of learning about OPM from distinct perspectives, e.g., local PST more from the local perspective, while nonlocal PST from the more distant, national perspective, potentially affected by prior experiences and level of knowledge.

Local PST studied at a university surrounded by oil palm plantations. Most likely, they experienced oil palm production and its impacts in their everyday life (e.g., oil palm trucks, the smog of forest fires, local economic growth). Their families, peers, and communities might also be involved in the oil palm business. Thus, it is likely that local PST have personal experiences and close, meaningful connections to OPM. This is supported by our quantitative findings that local PST perceived relatively high relevance of learning about OPM. Qualitatively, they referred more to the local subdimension in their relevance reflections compared to nonlocal PST.

(1) Curiosity, expectations, and knowledge gains: Nonlocal PST might have been more curious about learning about OPM initially due to their lack of prior personal experiences and knowledge on OPM compared to local PST. Nevertheless, nonlocal PST might also have prior knowledge on (other) plant cultivation or crop management. Making connections between the learning objects, here the educational unit, and the existing knowledge may promote relevance perceptions (see Hulleman et al., 2017; Liebendörfer and Schukajlow, 2020). While local PST likely have many connections between the unit and their prior knowledge, nonlocal PST might have made more new, meaningful connections. For example, nonlocal PST may have perceived science-based knowledge on OPM as relevant for other SSI close to their universities and other contexts (e.g., own gardening), as illustrated by this quote:

> "The way that the unit can be useful for me is to apply knowledge regarding plant care to other plants, especially regarding fertilization and weeding and the proper use of herbicides. [...] I can see the positive and negative impacts of oil palm plantations in Indonesia. In my future profession as a teacher, I can provide education to students about insight and knowledge about [...] oil palm [...], so that students can also find out how plant care can be applied to other plants [...]"
>
> [Translated response by nonlocal PST, ID 3].

Nonlocal PST could have had higher expectations, expressed as perceived relevance of learning about OPM. Although OPM might have been less familiar to them, it is still a prominent and relevant SSI in the everyday national media (Nida et al., 2021). National media emphasize the economic and developmental importance of oil palm and its negative consequences, highlighting its extrinsic relevance and influencing the perceptions of both local and nonlocal PST (see Tuncay et al., 2012). Thus, expecting to and actually making more new meaningful connections between learning about OPM through the educational unit and their existing knowledge might have led to higher relevance perceptions of nonlocal PST in comparison to local PST (see Liebendörfer and Schukajlow, 2020; Nida et al., 2021; Wiyarsi et al., 2023). As nonlocal PST probably gained their prior knowledge on OPM from media, they might have connected learning about OPM more to their existing nation-related OPM knowledge. This would also explain why they referred in their relevance responses more to the national subdimension in comparison to local PST.

(2) Openness to new science-based knowledge and optimism: Being less embedded in the local context and its established practices, nonlocal PST may be more open to embracing new science-based strategies for sustainable OPM. They might be less influenced by local wisdom and traditional knowledge that can lead to skepticism or indifference toward new approaches. In Indonesia, local wisdom plays a significant role in everyday life, education, and society (Zidny and Eilks, 2022; Wiyarsi et al., 2023). Since nonlocal PST engage with OPM more from an external perspective, they could be more optimistic about the potential and relevance of science-based knowledge for sustainable OPM. The following quote illustrates this perspective:

> "The content of the unit is useful for me, who aspires to become a teacher. This knowledge, at least when I don't own an oil palm plantation myself, can be conveyed to my students regarding the importance of sustainable palm oil management [and] provide knowledge for them to be [...] applied directly or conveyed again. Because the benefits and ways of managing oil palm must be understood by everyone, for future provisions in improving the economy."
>
> [Translated response by nonlocal PST, ID 36].

The discussion of prior experiences and knowledge, as well as newly gained knowledge as influencing factors underscores their crucial role in shaping perceptions (Duan and Fortner, 2005; Tuncay et al., 2012; Mahler, 2020; Yli-Panula et al., 2023), particularly relevance perceptions (Stuckey et al., 2013), of learning about SSI. This points to a limitation of our study [see Section 7 (3)].

From a broader perspective, the found plausible patterns raise the question if a spatial dimension and the locality of the SSI could be an amendment to the relevance model of Stuckey et al. (2013). Until now, the model comprises "only" a social, temporal, and intrinsic-extrinsic relevance dimension.

6.2 Learning about oil palm management perceived as more relevant for pre-service teachers individually and societally than professionally?—Ad RQ2

The individual, societal, and professional relevance perceptions of learning about OPM differed among Indonesian PST. Qualitatively, in their written responses to the reflection task, both local and nonlocal PST referred more to themselves individually ("I") than to collective identities ("We"). Local and nonlocal PST made much more relevance references unrelated to their profession than related to their future profession. Thereby, nonlocal PST had a higher probability of profession-related relevance references (contradicting H2c). However, the differences between individual and societal relevance as well as individual and professional relevance were not as clear in the quantitative results. These differences concerning the quantitative data depended

on locality of OPM for PST and on time. For example, the professional relevance perception of nonlocal PST was higher and increased much stronger from pretest to posttest than of local PST (contradicting H2a; partially supporting H2b).

First, we discuss our findings with respect to the professional relevance subdimension. Second, we discuss how the locality of OPM for PST influenced the individual and societal relevance subdimensions.

(1) Low professional relevance perceptions for teaching and learning about oil palm management: Although PST were not explicitly asked to relate to their future profession in their written relevance reflections, the relation of learning about OPM to their future profession as educators was part of the group discussion task in module IV "Reflect." So, why did PST refer more to their profession-unrelated areas of life than to their future profession as educators regarding their perceived relevance of learning about OPM? Potential reasons:

First, since PST were not explicitly asked, some may not have considered writing about the relevance for their future profession as educators. Furthermore, we restricted the qualitative coding to PST' future profession as educators. PST were still in their second or third study year and, thus, their professional identity development had just started. In the study by Nida et al. (2021), Indonesian PST were concerned that teaching and learning about palm-oil-based biodiesel as SSI was too difficult and less suitable for school education. Therefore, some PST might also have perceived that learning about OPM might be less relevant for their future jobs as teachers in schools.

PST may also have related learning about OPM as more relevant to others or other professional fields, e.g., more to the economic potential of OPM as indicated by the quote of the nonlocal PST (ID 36) above. This corresponds to a study across 22 Asian countries, including Indonesia, which revealed that educational curricula and policies in these countries tended to focus more on national economic growth than on sustainable development of society (Mochizuki, 2019).

Even if Indonesian PST perceived the relevance of learning about OPM, they might feel restricted in their impact as change agents (cf. Yli-Panula et al., 2023). Local PST likely encounter the seemingly unstoppable oil palm boom, its positive impacts, and the favorable image promoted by various stakeholders on a daily basis. This, in combination with persistent local wisdom and the perceived difficulty of teaching SSI, may have lowered their perceived role as change agents in this context. Consequently, for local PST, this could lead to lower perceived professional relevance as educators. Local PST perceived lower professional relevance compared to nonlocal PST, both quantitatively and qualitatively professional relevance in comparison to nonlocal PST. This could be explained by an inhibiting influence regarding professional relevance in the local context.

(2) Learning about oil palm management as nonlocal socioscientific issue promotes individual and societal relevance: The individual and societal relevance perceptions of learning about OPM differed between local and nonlocal PST. Curiosity, knowledge gains, and optimism/skepticism due to distance from or embeddedness to OPM have already been discussed as potential reasons for the locality effect in the previous Section (6.1). Here, we specifically discuss the effect of locality of OPM for PST with respect to individual and societal relevance.

Nonlocal PST in comparison to local PST:

- Perceived individual and societal relevance of learning about OPM higher (contradicting H2a),
- Perceived societal relevance increased more through the unit over time (partially supporting H2b),
- Had a higher probability of relevance references overall in their writing tasks, referring more to both pronouns "I" and "We," which respectively indicate individual and societal relevance (partially supporting H2c).

The perceived relevance for local PST regarding "useful to me" and "important for everyone to understand" did not significantly differ through the unit over time. For nonlocal PST, the relevance regarding "useful to me" was initially perceived higher than "important for everyone" (pretest). After completing the unit, nonlocal PST' perceived relevance regarding "important for everyone to understand" was more leveled up with the perceived relevance regarding "useful to me" (pretest to posttest).

Our findings suggest that perceived individual relevance aligns more with societal relevance over time for nonlocal PST. This meets the assumption that engaging with SSI can promote learners' societal perspective (Amos and Levinson, 2019; Holbrook et al., 2022). Combining nonlocal PST' increased societal relevance with the finding that nonlocal PST referred more to the national level in their reflections suggests that the unit promoted the societal-national relevance of learning about OPM for nonlocal PST. This corresponds to the findings by Nida et al. (2021), which indicate that PST studying at a university nonlocal to OPM perceived national and societal relevance of learning about the SSI palm-oil-based biodiesel.

Discussion-overarching, our findings allow us to conclude that learning about OPM is perceived as more relevant individually and societally than professionally for PST, particularly for nonlocal PST. Nevertheless, PST perceived relatively high individual, societal, and—quantitatively—professional relevance. This indicates a degree of identification with learning about OPM beyond individual goals, suggesting that engaging with SSI can promote societal relevance and bridge out-of-university experiences with the learning experiences in more formal settings (Stuckey et al., 2013; Nida et al., 2021). Identification with learning objects is beneficial for long-lasting engagement in education (Priniski et al., 2018). In this light, our findings are also encouraging with respect to PST' potential role as motivated multipliers for knowledge on science-based crop management strategies.

7 Limitations and future directions

(1) Expanding the study context: This study focused on Indonesian PST' relevance perceptions of OPM as one environmental SSI comprising scientific, social, as well as local, national, and global aspects. As our findings are promising, we see

high potential for future research to upscale the study context. We assume that our study approach is easily transferable to further SSI. However, it remains an open empirical question to what extent our findings depend on the present SSI context.

Furthermore, the participants were Indonesian PST in their second and third study year. It could be of interest to extend the present relevance research to further study groups worldwide and at different educational or professional stages, e.g., in-service teachers. In this regard, it could also be of interest how educational units addressing pedagogical content knowledge for SSI education promote relevance perceptions, especially the professional relevance subdimension (see Rochnia and Gräsel, 2022).

Bringing these points together, future research could investigate how relevance perceptions differ:

- Between comparable environmental SSI within one country, e.g., OPM (Sumatra) vs. citrus management (Bali) and between different regions of the world (see Duan and Fortner, 2005; Tuncay et al., 2012; Yli-Panula et al., 2023),
- Between different classes of SSI, e.g., environmental vs. health-related SSI (COVID-19, animal experimentation, smoking, etc.) (see Wiyarsi et al., 2023),
- Among PST at different stages and in-service teachers or students at school,
- Between different addressees of formal education in various regions of the world.

(2) More balanced sample composition: While nonlocal PST were from two universities on different islands with one study program each, local PST were enrolled in two study programs but came only from one university. Thus, it is of interest to find out if the findings remain the same when involving at least one further university with local PST.

(3) Better understanding PST' background: We collected as minimal personal data as possible in accordance with the guidelines of data minimization. Differences between origin and culture (e.g., ethnic groups or nationalities) (Song and Jiang, 2019; Hecht et al., 2021) as well as place of living might have influenced relevance perceptions. To answer corresponding research questions, surveying more personal data as well as data on prior personal experiences and knowledge aligned with utility value measurements are needed in future studies (Liebendörfer and Schukajlow, 2020).

(4) Further testing of methodological approach: The quantitative research is limited by self-reported measurements, the use of an asymmetric Likert-scale, and restrictions in the statistical model due to convergence issues. Concerning the qualitative research, potential translation and cultural challenges may have arisen throughout content analysis. Even if the German-Indonesian coder team intensively discussed the procedure beforehand and the final codes (consensus-building), we cannot completely exclude translation inaccuracies and intercultural misunderstandings. Furthermore, coding singular and plural first-person personal pronouns in responses to relevance reflection tasks, which fulfill the utility value criteria, seems to be a promising approach (e.g., Beigman Klebanov et al., 2017). However, it is only an indirect measure of perceived individual and societal relevance. It turned out that the pronoun coding supported the quantitative results in the current study. This is encouraging for future research to investigate the suitability for pronoun coding as indicator for individual and societal relevance perceptions.

(5) Expanding research on relevance intervention to the SSI context: We cannot determine the effect of the relevance reflection task on the perceived relevance as it was embedded as module in the educational unit. Furthermore, we did not include a measurement point before and after the reflection task in module IV in a control group design. Future research could investigate the relevance or utility value intervention effect and could also compare, e.g., effects of directly communicated vs. self-generated relevance interventions (see Hulleman and Harackiewicz, 2021; Soicher and Becker-Blease, 2023).

Our study suggests that actively promoting PST' relevance perceptions, e.g., through writing tasks, and evaluating the perceptions in a differentiated way has high potential for future research and practice.

8 Implications for relevant teaching and learning about socioscientific issues

Based on our findings, we argue that relevance, relevance dimensions and subdimensions should be used as more than a central selection or legitimation criterion within SSI and science education. Beyond considering extrinsic relevance for lesson planning, educators can actively and explicitly promote intrinsic relevance perceptions. From our results, we derive suggestions regarding the following two main practical implementations regarding promoting relevance perceptions for science and SSI education.

(1) Implementing relevance reflections in educational practice: Relevance perceptions can be promoted and assessed with relatively little time cost in teacher education—but also in school and higher education—following utility value approaches (Hulleman and Harackiewicz, 2021; Soicher and Becker-Blease, 2023). Our findings demonstrate that this approach can be effectively applied to learning about OPM as an SSI. Given our adaptation of the utility value reflection task, we assume that relevance reflection tasks can be adapted to SSI and science education contexts.

In teacher education specifically, understanding relevance perceptions can help to address PST needs and prepare them as change agents for challenging SSI (Nida et al., 2021; Winter et al., 2022). Understanding why PST may or may not perceive social relevance of SSI education can also help to meaningfully address the neglected social dimension of SSI (Friedrichsen et al., 2021). For example, knowing that PST perceive only little professional relevance in learning about OPM, we can further develop a relevance reflection task to explicitly prompt PST to write about their perceived professional relevance. Furthermore, the educational unit can be further developed by integrating more elements, which might foster professional relevance perceptions, e.g., through "hints for future teachers" embedded in the educational unit, which directly communicate relevance (e.g., Hecht et al., 2021) of teaching about OPM. Moreover, we

can present corresponding media, techniques, and tools for teaching about OPM as SSI at schools. Similarly, global relevance perceptions could be explicitly promoted by further highlighting OPM as global SSI, e.g., differences and similarities regarding OPM in Africa or South America, and integrating more the global consumer perspective into the educational unit.

(2) Considering the locality of SSI for relevant SSI education: Our findings show that PST perceive the relevance of learning about OPM as local or nonlocal SSI differently. Based on our discussion, we see that it is important for teaching and learning about local or nonlocal SSI to take PST' or learners' prior knowledge, experiences, and perceptions into account (see Herman et al., 2021). We agree with the assumption that if educators aim to promote the individual relevance of learning about SSI, they can select local SSI as they are more closely connected to personal experiences and everyday life (Sadler, 2004; Duan and Fortner, 2005).

Beyond, we suggest that educators should also select nonlocal SSI for promoting individual and societal relevance (cf. Sadler, 2004; Duan and Fortner, 2005). PST should be prepared to support learners for both local and nonlocal SSI considering local, national, and global subdimensions of spatial relevance (Tuncay et al., 2012). If possible, the integration of both local SSI close to PST' universities and nonlocal SSI in teacher education (e.g., through field trips to other regions via place-based education study programs; Herman et al., 2021) could be beneficial to foster relevance perceptions. In the following, we recommend different approaches for relevance promotion and learning about SSI depending on the locality of SSI for the learners:

For local PST, we suggest providing (more) opportunities to share, discuss, and reflect personal experiences with respect to the SSI at hand in a safe environment (Stuckey et al., 2013; Herman, 2018). Furthermore, it seems crucial for environmental SSI, such as OPM, to address local wisdom and traditional knowledge (Zidny and Eilks, 2022). It could be beneficial to fruitfully discuss potential synergies and differences between scientific and local, traditional, and cultural knowledge—also with respect to relevance perceptions. In this regard, especially for PTS, but also for all learners, it can be important to cope with the differences among peers, the community, and further stakeholders.

For nonlocal PST, we suggest providing activities to engage with local perspectives and perceptions but also explicitly about relevance perceptions of learning about the SSI at hand. Ideally, a prepared exchange in a safe environment between local and nonlocal PST could benefit relevance perceptions and meaningful SSI education. In Indonesia, two potential opportunities for PST exist: First, the "independent campus" (Kampus Merdeka) program actively promotes cross-university exchange and common learning in courses by allocating "free" credits for course choices (Direktorat Jenderal Pendidikan Tinggi Kementerian Pendidikan dan Kebudayaan, 2020). Second, upon the completion of their bachelor's degree in education, Indonesian PST participate in a program called "pre-service teacher professional education (Pendidikan Profesi Guru Prajabatan)." This program enables PST to exchange and reflect on teaching and learning experiences with other PST from various regions across Indonesia in online courses (Direktorat Pendidikan Profesi Guru, Direktorat Jenderal Guru dan Tenaga Kependidikan, Kementerian Pendidikan, Kebudayaan, Riset, and dan Teknolog, 2023).

Implementing relevance reflection tasks and considering the locality of SSI in educational practice can support PST' perceived spatial and social relevance perceptions, ultimately promoting motivated and meaningful engagement with SSI for learners and future educators.

9 Conclusion

This study investigated Indonesian PST' perceived spatial and social relevance of learning about OPM as a local or nonlocal SSI. Our results showed that the locality of OPM influences Indonesian PST' relevance perceptions. Nonlocal PST perceived higher overall relevance and focused more on the national subdimension, while local PST referred more to the local subdimension. PST tendentially perceived learning about OPM to be more individually and societally relevant than professionally relevant. Over time, the perceived societal and professional relevance increased more for nonlocal PST compared to local PST.

Relevance reflection tasks can effectively assess PST' intrinsic relevance perceptions of SSI, such as OPM. Explicitly considering perceived spatial and social relevance dimensions and the locality of SSI can enhance meaningful SSI education. Adapting these tasks to science education contexts across educational levels can hold high potential for future practice and research. Moreover, future science education studies can explore professional relevance of PST concerning SSI teaching and learning through educational units focusing on pedagogical content knowledge in addition to content knowledge, e.g., fostering reasoning, decision-making and perspective-taking competencies, and eventually also on pedagogical knowledge (see Rochnia and Gräsel, 2022).

While PST' intrinsic relevance perceptions may differ from extrinsic relevance determined by curricular requirements and societal expectations, both play a crucial role in preparing PST to become change agents and multipliers for sustainable development. Understanding PST' subjective perceptions provide valuable insights for addressing SSI in teacher education.

Our findings on the spatial and social relevance perceptions of learning about OPM as a local or nonlocal SSI highlight the importance of tailoring teacher education to address the diverse ways in which future educators connect with SSI. Our study contributes to knowledge on how to prepare PST to act as motivated change agents for sustainable development. Science teacher education stands to benefit from taking PST' spatial and social relevance perceptions and the locality of SSI into account.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Indonesian National Research and Innovation Agency (BRIN). The studies were conducted in accordance with the local legislation and

institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

FM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. GN: Conceptualization, Data curation, Methodology, Writing – review & editing. FR: Conceptualization, Formal analysis, Visualization, Writing – review & editing. IA: Methodology, Writing – review & editing, Conceptualization. LS: Methodology, Writing – review & editing. UY: Writing – review & editing. SB: Conceptualization, Investigation, Funding acquisition, Methodology, Project administration, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1421716/full#supplementary-material

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