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Perspectives from science teacher educators on the potential contribution of Sámi traditional knowledge to sustainable development

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Introduction: This study investigates how Sámi traditional knowledge is integrated in science teacher education in Norway, and what teacher educators declare about its potential contribution to sustainable development.

Methods: Data was collected through an anonymous electronic survey and analyzed by means of both qualitative and quantitative methods. Thirty-nine respondents from 15 teacher education institutions in Norway participated in the study.

Results: According to the respondents, most science courses explicitly mentioned Sámi traditional knowledge. The most common Sámi topics taught in science in kindergarten education, were the seasons, preparing traditional food, constellations and reflecting about how traditional knowledge can contribute to sustainability. For primary school teacher education, the most common Sámi topics were the constellations, conflicts with building of windmills parks in traditional reindeer grazing areas, traditional use of plants and seasons. The self-declared level of knowledge on Sámi traditional knowledge was rather low and the majority of respondents expressed the intention to improve their competence by reading or attending courses. The thematic analysis of the answers to the question about how Sámi traditional knowledge could contribute to sustainable development, identified four main Sámi themes: traditional use of resources, view of nature, local knowledge versus Sámi traditional knowledge, and social sustainability. Our results confirmed that teaching Sámi traditional knowledge poses a significant challenge for science teacher educators, both as consequence of their perceived knowledge and the limited amount of time available for teaching. Some respondents found the subject not relevant for the students, whereas other were challenged by its sensitivity or by the availability of culture bearers. The contrast between traditional knowledge and western science as different views of knowledge was also mentioned.

Discussion: Based on teacher educators' perspectives, we propose that adopting a Two-Eyed Seeing approach in science teaching could promote critical thinking, by enabling a reflection on our resource utilization and on our human-nature relationship. Some of the challenges associated with lack of time and knowledge could be addressed by promoting further education for science teacher educators, building a network of knowledge bearer that could be invited in the teacher courses, or reevaluating the courses content to make place for Sámi themes. This would also promote decolonization and inclusion of the Sámi people, thus contributing to several aspects of sustainability.

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KEYWORDS

decolonization, indigenous knowledge, teacher education, sustainability, text mining, two-eyed seeing, view of nature, western science

1 Introduction

The Sámi have the status of indigenous people in Norway (International Labour Organisation, 1990), and Sámi history, culture, and society hold a significant place in the curriculum and in the regulations for teacher educations. The core curriculum for primary and secondary education states that all students should gain insight into Sámi culture, history, rights, and societal life (Norwegian Ministry of Education and Research, 2017a). Furthermore, the framework plan for kindergartens states that kindergartens should highlight Sámi culture and help to ensure that the children develop respect for and solidarity with the diversity of Sámi culture (Norwegian Ministry of Education and Research, 2017b).

Sámi culture should be represented in schools and kindergartens, both to educate all children in Norway and to ensure that Sámi children see their own culture reflected in the school environment. Moreover, teaching traditional indigenous knowledge in schools can help indigenous students maintain pride in their own culture (Murray, 2015). However, Sámi traditional knowledge is difficult to access for schools and teacher education (Kvivesen et al., 2023) and didactic literature on Sámi topics is notably scarce within elementary school subjects (Figenschou et al., 2023).

To our knowledge how Sámi traditional knowledge is included in science teacher education has never been investigated for Norway, although including indigenous communities in the discourse about sustainability is crucial. This for fulfilling both the social component of sustainability and the aims of Agenda 30 (United Nations, 2015), which implies that indigenous communities and ethnical minorities actively participate in the political debate and are not marginalized (Bansal et al., 2024; Magni, 2017). Recently, in Norway, the Truth and Reconciliation Commission released its report, urging authorities to enhance education about the Sami in the educational system (The Truth and Reconciliation Commission in Norway, 2023).

For these reasons, we investigated the following questions:

1 To which extent is Sámi traditional knowledge integrated in science teacher education in Norway?
2 What are the perspectives of teacher educators towards Sámi traditional knowledge and its potential contribution to sustainable development?

The Sámi represent the sole indigenous group in Northern Europe, with their homeland, Sápmi, spanning the northern regions of Norway, Finland, Sweden, and the Kola Peninsula in Russia. Most of the Sámi people, ca. 55,000 (Olsen, 2020), live in Norway. Traditionally, the Sámi have sustained themselves through reindeer herding, fishing, farming, and natural harvesting, practices that have preserved their language and cultural heritage. The profound connection and understanding of nature inherent in Sámi culture continue to influence traditional industries, where Sámi traditional knowledge remains prevalent (Nergård, 2019).

Sámi traditional knowledge is the collective wisdom and skills of the Sámi people, which have been passed down across generations to enhance their way of life. This knowledge has been preserved and shared through oral traditions and hands-on interaction with nature. Each generation contributes to its enrichment, ensuring that traditional knowledge forms a continuous link between the past, present, and future (Guttorm, 2018). Research shows that indigenous knowledge is underestimated and could represent an important contribution to our knowledge on human-nature interaction and help achieving sustainable development (David, 2024).

Sustainable development is defined as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). To achieve sustainable development, we need to integrate environmental, economic, and social perspectives. Our conceptual framework is based especially on Sustainable Development Goal (SDG) 4 of Agenda 2030 on quality in education (United Nations, 2015), which quotes, "By 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development" (SGD 4.7). The term *sustainability* comes from the field of ecology, and it indicates the conditions necessary for an ecosystem to sustain itself over the long term (Holden et al., 2014).

A critique of the framework of sustainable development, which extends also to education for sustainable development (ESD), is to be too anthropocentric, valuing living organisms according to their ability to provide ecosystem services to humans, such as oxygen and timber production (IPBES, 2019), placing a big emphasis on monetary values and failing to consider the intrinsic value of nature, which is inherently challenging to place a monetary value on (Kopnina, 2014). In this paper we will treat sustainable development and sustainability as synonyms of each other.

The recognition of indigenous knowledge and how it can contribute to sustainable development has increased throughout the world (Zidny et al., 2020). There are several examples of areas managed by indigenous people, maintaining a high biological diversity, while in indigenous areas dominated by settlers there is more overharvesting of resources which leads to deforestation, desertification, pollution and depletion of fresh water (Corntassel, 2014). In different regions of the world traditional ecological knowledge plays a role in monitoring and managing ecosystems, building up their resilience (Berkes et al., 2000). This suggests that indigenous people can contribute with valuable knowledge for a more sustainable development. An example of this is the Nisqually tribe, in western Washington State, where knowledge based on the systematic acquisition of site-based knowledge over a longer period of time contributes to the improved management of the Nisqually river system (Johnson et al., 2016). Successful integration of indigenous knowledge and western science has also been achieved for the analyses of changes in the Saskatchewan River Delta in Canada (Abu et al., 2019).

Despite that, there has been limited dialogue between knowledge systems rooted in western science and those based on indigenous

knowledge, as the latter has often been excluded from academic discourses (Johnson et al., 2016). The view that indigenous knowledge can give an important contribution to solving sustainability challenges can be found in several international agreements, including in the Convention on Biological Diversity (United Nations, 1992), in government documents, such as Australia's Strategy for Nature 2024–2030 (Australian Government, 2024) and in governing documents for education (Norwegian Ministry of Education and Research, 2014, 2016a, 2016b, 2017a, 2017b, 2019). The thematic assessment for sustainable use of wild species states that indigenous and local knowledge is often underutilized and undervalued and that "co-production of knowledge by indigenous peoples and local communities and scientists can create robust information about social and ecological conditions and enhance decision-making" (IPBES, 2022, p. 32).

The symbolic image of Two-Eyed Seeing has been used as a way to maintain together the holistic and reductionistic approach to several interconnected scientific fields, such as biology, health and sustainability (Hatcher et al., 2009; Bartlett et al., 2012; Fang and Casadevall, 2011), where both the approaches can be "stereoscopic" and complementary ways to study and understand complex phenomena. A methodological review on how to apply this method in research has been published by Wright et al. (2019).

Typically, sustainability problems are associated with a large degree of uncertainty and insufficient information (Block et al., 2019), and in such situations, it is particularly important to combine different knowledge systems (Johnson et al., 2016). Global climate change is an example of a topic for which using both knowledge systems would provide a better understanding than relying solely on western science (Johnson et al., 2016). Sustainability challenges are inherently complex and influenced by values, making an interdisciplinary approach to education for sustainability widely regarded as the most effective (Block et al., 2019). Indigenous knowledge has the potential to be one of the interdisciplinary aspects (Snively and Williams, 2018). Integration of traditional knowledge in sciences teaching has also been investigated in South Africa (Mkhwebane, 2024), New Zealand (Glynn et al., 2010) and Canada (Aikenhead and Elliott, 2010). A recent study reviewed pedagogical practices integrating indigenous knowledge systems in science teaching and concluded that these can be successfully applied to enhance critical thinking skills and generate new knowledge (Ogegbo and Ramnarain, 2024).

Governing documents for education (Norwegian Ministry of Education and Research, 2014, 2016a, 2016b) also promote the inclusion of several knowledge systems in teaching, in order to allow students experience how western science and traditional knowledge can contribute to a holistic ecological understanding. However, this can be challenging due to the influence of western standards in education, such as curriculum design and testing practices. In other words, it is difficult to maintain a fair approach to indigenous knowledge as the inclusion takes place on western terms (Lowan-Trudeau, 2012).

The national guidelines for primary school teacher education 1–7 and 5–10 and early teacher education govern the teacher education institutions in Norway (Norwegian Ministry of Education and Research, 2014, 2016a, 2016b) and together with the regulations (Norwegian Ministry of Education and Research, 2010, 2012) must form the basis for study plans at the individual institution (§4). The core values for primary school teacher education emphasize the Sámi cultural heritage and dissemination of knowledge about the history, culture, social life and rights of the indigenous Sámi people. For the kindergarten teacher education, the comments following the regulations underline that there are special obligations in relation to the Sámi people. Furthermore, both documents state that the study plans at the various teacher education institutions must contain directions on academic content including Sámi subjects. In the science curriculum for compulsory school, Sámi traditional knowledge is linked to the sustainable use of resources and conservation of natural diversity (Norwegian Ministry of Education and Research, 2019).

2 Methods

In February 2024, an invitation to participate to an electronic survey about Sámi traditional knowledge in science teacher education was sent to all members of the Norwegian Network for Teacher Educators in Science. This network includes 205 members from 17 institutions who were also invited to forward the survey to other science teachers' educators outside the network, which resulted in 39 participants in total from 15 institutions. The survey included eight questions, two of which were open questions (Table 1). The data collection ended in April 2024.

We then did a qualitative analysis by thematic analysis (Braun and Clarke, 2006) and a quantitative analysis by text mining (Feinerer et al., 2008). The reason for this mixed approach was to provide more robust results by combining different methods. The thematic analysis was conducted with a realistic approach. We first worked independently reading the text several times to identify patterns and reoccurring themes in the data. Afterwards, we compared the results on the potential themes and agreed on the final ones, on which we based our report. The choice of the final themes was made by both merging similar themes into one at the same time as we tried to preserve diversity. The thematic analysis was done manually by using colors to mark the text. The text mining analysis was done with the R packages *tm* (Feinerer and Hornik,

TABLE 1 Questions and types of answer in the survey on Sámi traditional knowledge in science teaching conducted in February–April 2024 in Norway among educators in teacher training courses.

N	Question	Type
1	In which educational institution do you work?	Multiple choices
2	Which teacher education programs do you teach?	Multiple choices
3	Is Sámi traditional knowledge/culture explicitly mentioned in your course plans?	Y/N
4	What themes/activities or theoretical approaches do you take up with students that are explicitly linked to Sámi traditional knowledge in science?	Multiple choices
5	What is your level of knowledge about Sámi traditional knowledge in order to teach about it on the teacher education course?	5 levels Likert
6	How would you like to increase your level of knowledge about Sámi traditional knowledge?	Multiple choices
7	In what way do you consider that Sámi traditional knowledge can contribute to sustainable development?	Open
8	What challenges do you see in teaching traditional Sámi knowledge in science?	Open

2024) and *SnowballC* (Bouchet-Valat, 2023) and *wordcloud* (Fellows, 2018) in the statistical program R (R Core Team, 2022). The Norwegian text from the open questions was translated into English. After removing common English stop words such as "and," "or," "for," by using R commands, we grouped words with very similar meaning into one word to reduce redundancy. For example, we changed "whole" into "entire" since both terms were used by the respondents. We then transformed important words to the plural form to avoid having both the plural and singular form for the same word. We removed some words which were included in our question and therefore redundant, such as for example "traditional knowledge" or "Sami" and merged words that together formed a concept so that it could be detected by the program. For example, "view of nature" became "viewofnature." Finally, we computed the frequency rank of the remaining words, which were also used to make a word cloud. Associations between the most common words were assessed by the function *findAssocs* in the R package *tm* (Feinerer and Hornik, 2024), where the coefficient varied between 0 and 1 and a score of 1 indicated that the two words were always found together, similarly to a Pearson correlation test.

2.1 Ethical considerations

The study followed the general ethical standards approved by the National Committee for Research Ethics in the Social Sciences and the Humanities (2024). The electronic survey was anonymous and did not include background data such as gender, age and teaching courses, that could reveal the identity of participants.

3 Results and discussion

3.1 Overview of the data

In total, 39 science teachers' educators from 15 different Norwegian teacher education institutions (out of 23) covering the northern, central and southern part of the country participated in the survey and 29 educators completed it, whereas the remanent 10 partially answered it. Five institutions were represented by 4–6 respondents, whereas the majority had 1–3 respondents. A respondent could teach several courses. Most respondents were involved in several types of education and the most common combination was kindergarten and primary school teacher education.

It is worth mentioning that the number of hours dedicated to science teaching can vary and occur at different stages of the courses depending on the course profile. For example, for kindergarten teacher education, different institutions can offer several parallel profiles such as outdoor life, arts, cultural diversity, and so on. Therefore, teachers from the same institution might teach courses with different profiles and study plans. However, to preserve the anonymity of the survey, we did not ask in more detail which courses the respondents taught.

It is important to note that our study did not include all Norwegian teacher education institutions (15 out of 23) and had a relatively small sample size. Some institutions were overrepresented in the dataset. However, teachers from the same institutions have different backgrounds and degrees of familiarity with Sámi traditional knowledge, so their answers were not expected to coincide.

The open questions in our survey were sometimes answered shortly or not answered at all. Another limit with our study, for what concerns the question about the level of knowledge of the respondents, is that we have to assume that they are not only honest but also able to evaluate their competence on the subject. Interviews might have been a more suitable data collection method to ensure that all participants expressed their opinion. Yet, qualitative surveys are less resource-demanding to administer (in terms of both time and funding) and ensure the anonymity of the respondents, which might impact their willingness to participate and honesty in the answers. Furthermore, qualitative surveys can provide richness and depth, when analyzed as a whole, even if the individual responses are short (Braun et al., 2021).

3.2 Sámi traditional knowledge in science course plans and taught topics

According to the respondents, most science courses explicitly mentioned Sámi traditional knowledge, although this information was not always consistent across institutions. This might indicate uncertainty about the precise content of course plans, however it might also be due to variation in content among courses from the same institution. While study plans at teacher education institutions are expected, according to the Norwegian National Guidelines, to include academic content also on Sámi subjects, a variable proportion of course plans actually did so, with a higher proportion (69%) reported for kindergarten education compared to basic teacher education (38%).

This is not surprising, since national guidelines for kindergarten education differ from primary school teacher education to a significant extent when it comes to Sámi. The kindergarten teacher education is themed, where one of six themes includes the Sámi (Indigenous people's perspective and Sámi culture). Furthermore, Sámi is included in two of five areas of knowledge: knowledge of the history of the Sámi as an indigenous people, knowledge of different Sámi cultures and everyday life, and making Sámi culture visible in education. This is reflected in the learning outcome formulations. This is in contrast to the national guidelines for primary school teacher education, where Sámi themes are neither in the presentation of the subjects (Science 1 and 2) nor in the learning outcome formulations. In the new framework plan for the content and tasks of kindergartens the word Sámi is mentioned 57 times (Norwegian Ministry of Education and Research, 2017b) as an attempt to make it more inclusive and decolonizing (Danielsen et al., 2023). As a comparison, the framework plan from 1996, presented Sámi culture as one among the other minorities and stated that kindergartens should protect "the good Norwegian childhood" (Korsvold, 2011).

Figure 1 shows an overview of the topics addressed with students which are explicitly linked to Sámi traditional knowledge in science. For kindergarten education, the most common Sámi topics were the seasons, preparing traditional food, constellations and reflecting about how traditional knowledge can contribute to sustainability (Figure 1A). For primary school teacher education, the most common Sámi topics were the constellations, conflicts with building of windmills parks in traditional reindeer grazing areas, traditional use of plants and seasons (Figure 1B). This is consistent with the results from a survey conducted in the southern part of Sápmi region of Norway in primary and secondary school, where in Natural Sciences, all informants reported teaching the topic "Sámi traditional use of animals, plants, and fungi" (Holand and Haugan, 2024).

3.3 Self-declared level of knowledge

The self-declared level of knowledge on Sámi traditional knowledge was rather low. Almost 60% of respondents declared they had very little or rather little knowledge, 14% meant they had a rather high level of knowledge, and none declared having very high knowledge (Figure 2). Although two participants stated that they did not need to increase their knowledge about the topic, the majority of respondents expressed the intention to read more or even attend courses to improve their competence (Figure 3). Similarly, Norwegian primary and secondary school teachers reported a general lack of competence and demanded more emphasis on Sámi topics in teacher education programs (Holand and Haugan, 2024). However, the same authors also report that in 2015, several colleges and universities cancelled further education in Sámi culture, history, and social studies due to the low number of applicants. The ongoing decolonization process, along with updates to the kindergarten framework plan and primary school curriculum, should encourage teacher educators to attend such courses. Nevertheless, it appears that significant changes in this area have yet to occur (The Truth and Reconciliation Commission in Norway, 2023).

3.4 Sámi traditional knowledge contribution to sustainable development

The thematic analysis of the 23 answers from the open question about how Sámi traditional knowledge could contribute to sustainable development, identified four main Sámi themes: traditional use of resources, view of nature, local knowledge versus Sámi traditional knowledge, and social sustainability. In addition, some answers suggested that Sámi traditional knowledge could contribute but not always, and one respondent did not know.

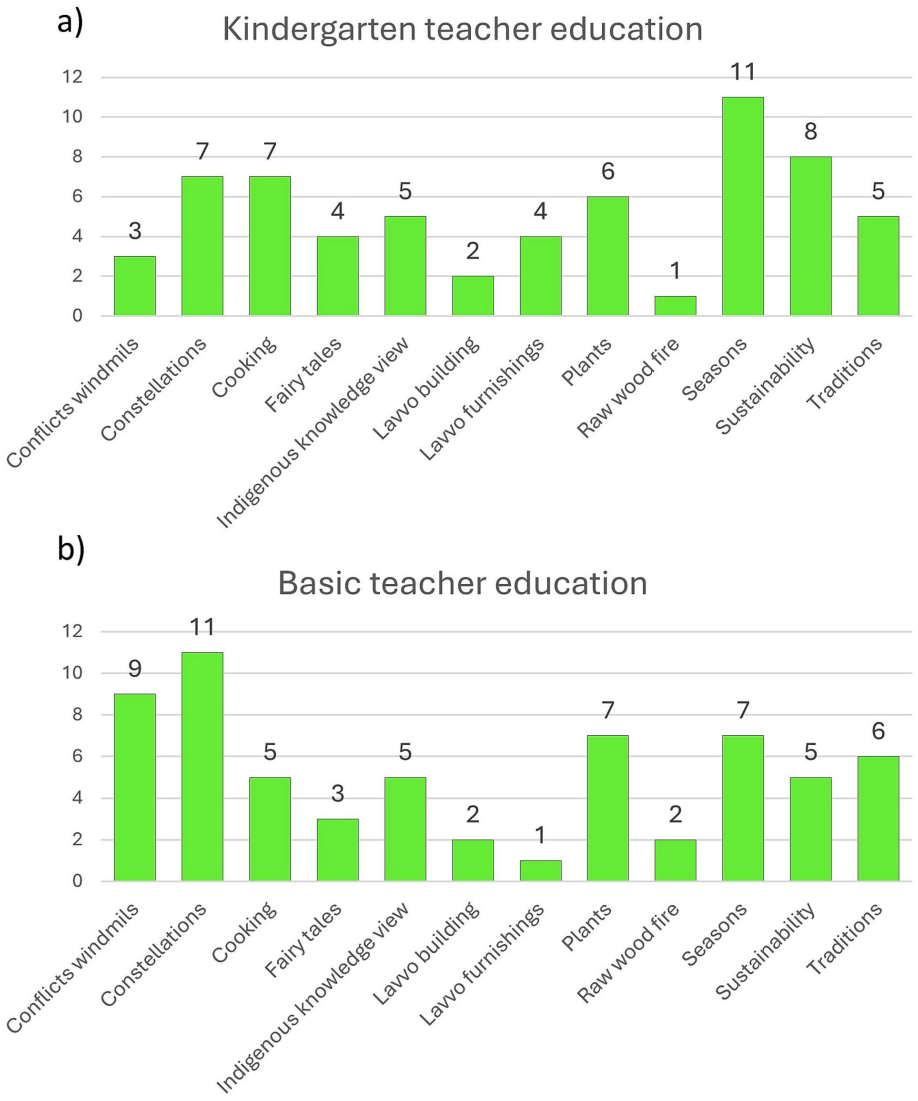

FIGURE 1
Number of times that themes/activities or theoretical approaches explicitly linked to Sámi traditional knowledge in science were taken up with students in **(A)** kindergarten and **(B)** primary school teacher education according to the survey on Sámi traditional knowledge in science teaching conducted in February–April 2024 in Norway. Lavvo is the traditional Sámi tent.

Most respondents (15 of 23 answers) suggested that the traditional Sámi way of using natural resources was relevant for sustainability and learning about this aspect could contribute to adopting more sustainable habits. Examples included eating the whole animal (therefore reducing food waste), following seasonal availability of food, and relying on more local food. A respondent for example answered "There are parts of Sámi traditional knowledge that are about taking care of nature and not using up the resources. When one slaughters a reindeer, one uses everything from the animal, the organs, meat, skin, etc., for food. This can contribute to sustainable resource utilization." Indeed, the way in which we utilize our resources, importing food from long distances instead of relying on local harvested products, and the food waste that is typically associated with modern food systems, are not sustainable. Agriculture, both grazing land (27%) and cropland (12%), is the prevalent type of land use on our planet (IPCC, 2019). This sector is responsible for one third of global greenhouse gas emissions (Crippa et al., 2021) and it is the main cause of deforestation, habitat loss, freshwater withdrawals, and water pollution on a global base (Halpern et al., 2022).

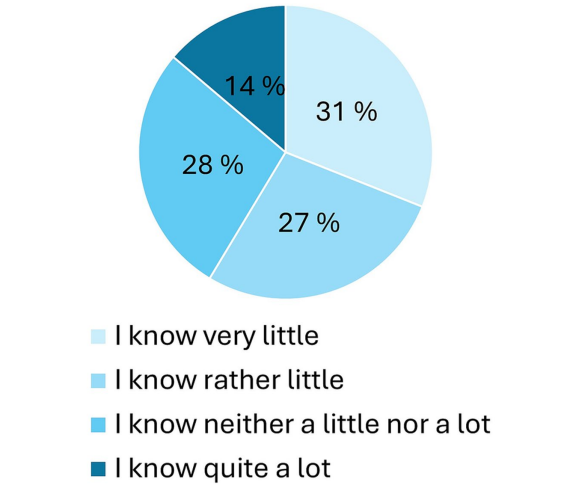

FIGURE 2
Self-declared level of knowledge according to the survey on Sámi traditional knowledge in science teaching conducted in February–April 2024 in Norway (n = 29).

Moreover, Sámi view of nature was thought to be especially relevant for sustainable development (five of 23 answers). In fact, Sámi view of nature was reported to be less anthropocentric and characterized by less "greed" and a stronger respect for nature compared to common western view of nature. For example, one respondent said, "Traditional Sámi knowledge can contribute to sustainable development with regard to the view of nature, that one should not take more from nature than needed, that one should treat nature with respect and not leave traces behind." The idea that indigenous view of nature and of the human-nature relationship differ substantially from western traditional view of nature has been expressed by many authors (e.g., Booth, 2003; Mazzocchi, 2006; Zidny et al., 2020). Indigenous people's way of looking at the world and nature has the potential to provide insight into environmental ethics and a deeper understanding of the connection between humankind and the planet's systems (Murray, 2015). Failing to attribute an intrinsic value to nature and the tendency to apply monetary terms to it has been typical of the western anthropocentric approach to conservation (Kopnina et al., 2018).

On the other hand, some of the respondents (four of 23 answers) also emphasized that it can be difficult to distinguish between local knowledge and indigenous knowledge. One of the informants for example wrote "Sámi knowledge and generally northern Norwegian

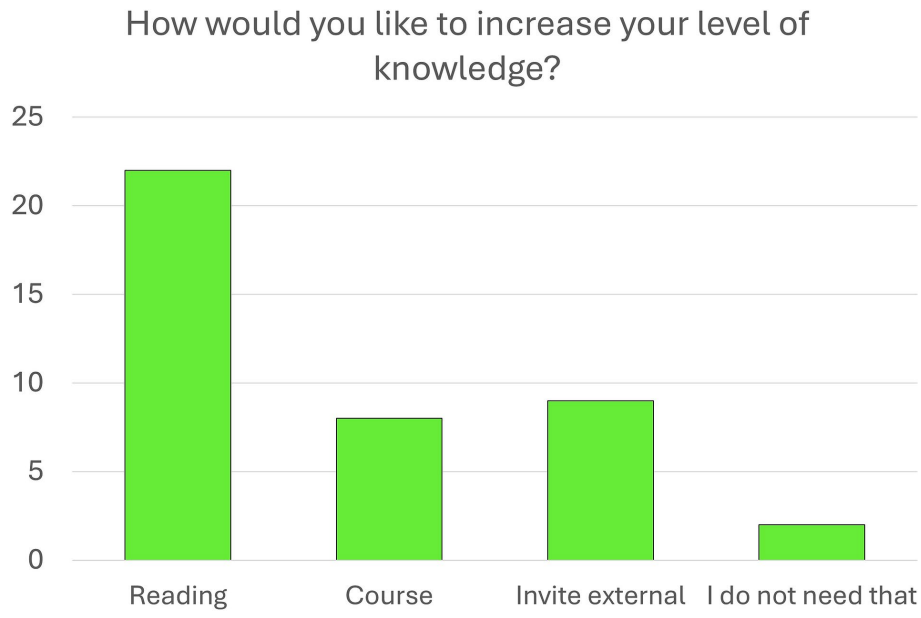

FIGURE 3
Number of times that different approaches were eventually chosen as a preferred way to increase knowledge according to the survey on Sámi traditional knowledge in science teaching conducted in February–April 2024 in Norway (multiple-choices allowed).

traditional knowledge are based on using local areas for, among other things, harvesting." Pastoral traditions, both Norwegian traditional sheep herding and Sámi traditional reindeer herding could be an inspiration towards a more sustainable way of using natural resources. Compared to the modern food systems, they are similar in the way of keeping animals, using the whole animal for food and clothing, growing plants, relying on local food, seasonal diet, useful plants, self-preservation rather than overharvesting and accumulating resources. Indeed, the traditional nine-component model for understanding sustainable Sámi reindeer husbandry (Eira et al., 2016) is rather different from the model used by the Norwegian state. In fact, the first is based on observation of reindeer behavior and condition and seek to adapt to changes in the environment, the second is based on monitoring carcass weight, composition of herds and the carry capacity of the habitat, seeking to maintain stability in the system (Johnsen et al., 2023). This flexibility and enhancing of resilience are aspects that could possibly contribute to sustainability.

Some of the respondents (five of 23 answers) underlined several practices of Sámi modern reindeer husbandry, which are not sustainable. One of the respondents wrote: "However, it is problematic that the practices themselves are not sustainable, and therefore one cannot see upon Sámi knowledge as equivalent to sustainability." Other examples were the use of feed that is grown abroad and cultivated with artificial nitrogen (derived from oil), or the use of helicopters, and all-terrain vehicles in natural areas to monitor the animals. Another aspect that was brought up is the size of the herds that are not always adjusted to the carrying capacity of the habitat. This might result in overgrazing of lichens, although there is an ongoing debate on that, which is a source of conflicts when the Norwegian government imposes Sámi reindeer herders to heavily reduce herd sizes (Johnsen et al., 2017). The question was also raised whether there is any traditional use of nature left in the world and, if yes, whether this way of living is a consequence of a free choice or not.

This question is part of the debate about the "ecologically noble savage myth" (Hames, 2007). From the 17th century the "noble savage" has been idealized symbolizing humanity innate goodness not yet corrupted by civilization, living in harmony with nature. This concept has proven not to be entirely correct, because there are many examples of cultures that disappeared in the past because they overharvested their natural environment (e.g., Hames, 2007; Mazzocchi, 2006). Furthermore, a more sustainable way of living might have been consequence of low population density, lack of technology and lower consumer demand, defined by Hunn (1982) as "epiphenomenal conservation," opposed to "true conservation" (Hames, 2007). This way of thinking bears imbedded a view of indigenous people as static and unable to develop, putting different expectations on them than on other peoples (Nadasdy, 2005). Traditional knowledge is not expected to be static, but to constantly be updated by input from the new generations (Guttorm, 2018). In other words, we cannot expect Sámi people not to use modern husbandry methods at all. Especially when borders and conflicts between neighboring countries, that were part of the migratory routes of Sámi reindeer herders, have forced them to become more stationary and therefore increase the grazing pressure on the pastures. Likewise, global warming and the consequent changes in ice cover distribution have made it extremely challenging to follow the traditional migration routes and forced many reindeer herders to rely on artificial feeding and use trucks or other motorized aids to move between winter and summers pastures (Rasmus et al., 2022). The point is not in finding out whether today's Sámi live more sustainably than the rest of Norwegians, but in combining aspects from both knowledge views that can together contribute to preserve the balance in ecosystems.

Some respondents also declared that teaching Sámi traditional knowledge in science could contribute to the component of sustainable development that takes place in the social sphere (three of 23 answers). It was mentioned that this type of knowledge also contributes to a stronger feeling of belonging and gives the children competence to act. In fact, including indigenous knowledge in science teaching can maintain or increase students' appreciation of local knowledge and contextualize the science curriculum through a cultural (and perhaps more concrete, relevant) context. In addition, a respondent reported that colonialism and a skewed distribution of power is not sustainable, and it is often the starting point for many sustainability-related conflicts. Indeed, reflecting on colonialism and adopting the Two-Eyed Seeing approach could be important for social sustainability and looking at sustainability-related conflicts from both sides might help to understand them and contribute to solving them.

The results of the quantitative analysis confirmed those of the qualitative analysis of the text. The most important words were "use," "resources," "food," "animal," "modern," "care," "viewofnature" and "entire" (Figure 4). In Figure 4 the size of the words is proportional to their relative frequency in the text made by pooling together all answers to the open question about how Sámi traditional knowledge potential contribution to sustainable development. When we set the lower limit for the association coefficient to 0.75, we found that the word "food" was strongly associated with "animals," "clothing," "cultivating," "locally," "plants," "seasonal."

Similarly, the term "viewofnature" was strongly associated with "today," "anthropocentric," "western," "contribution," "culture" and "change" (coefficient ≥ 0.89 for all terms). The term "entire" was strongly associated with "animal."

3.5 Challenges in teaching Sámi traditional knowledge

Our results, both from the question about self-declared level of knowledge and from the last open question, confirmed that teaching Sámi traditional knowledge poses a significant challenge for science teacher educators. The thematic analysis of the 24 answers from the open question about the challenges associated with teaching Sámi traditional knowledge in science classes, identified six main themes: little knowledge on the subject, limited amount of time, scarce relevancy for students, sensitivity of the issue, difficulty in finding culture bearers, different views of knowledge.

Several respondents pointed out their own low level of knowledge (or the low level of knowledge of teachers in general) on the subject (nine of 24 answers) and the limited amount of time available in science classes to cover several themes, especially if one should aim at achieving a deep and not superficial learning (eight of 24 answers), as described by Krajcik and Shin (2023). The scarce relevancy for students living outside Sámi-areas of Norway, or the lower importance compared to other subjects necessary for the overall understanding of science were also mentioned among the challenges (three of 24 answers). The sensitivity of the issue (three of 24 answers) included

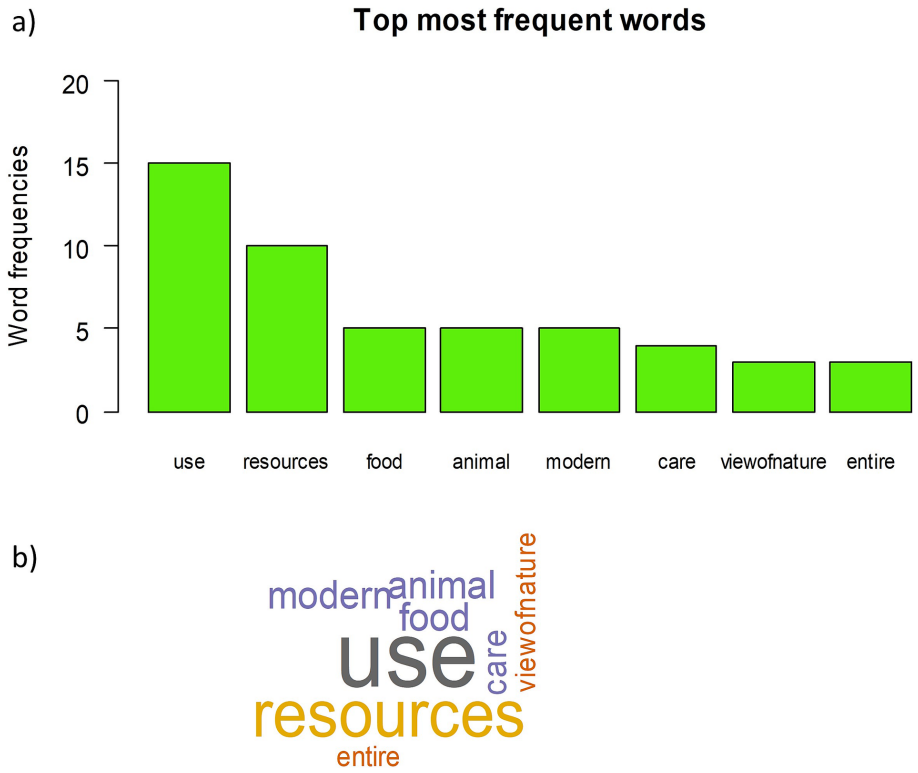

FIGURE 4
(A) Plot showing the eight most frequent words and **(B)** word cloud based on words used at least three times by respondents to answer the question about how Sámi traditional knowledge can contribute to sustainable development (number of answers = 23).

both the need to avoid stereotypes and exotification and the difficulty in touching a subject associated with conflicts in herding areas, especially in the northers part of the country. This aspect was also associated with the difficulty in finding culture bearers (two of 24 answers). Another challenge was identified by the fact that Sámi traditional knowledge is based on own experience and faith not on facts and therefore Sámi traditional knowledge and western science are based on fundamentally different views of knowledge (two of 24 answers). One respondent pointed out the difficulty in distinguishing between Sámi traditional knowledge and local traditional knowledge. In addition, one respondent had not taught the subject and two did not see any special challenge associated with teaching it.

It is true that many of the respondents teach outside the Sámi-areas of Norway and that there might be students from other minority groups attending the classes. However, the Sámi are recognized in Norway as indigenous people, which makes their position distinct from other national minorities in the Norwegian society (Andreassen and Olsen, 2020; Danielsen et al., 2023).

Indigenous knowledge and western science belong to two different knowledge systems; however, they represent separate but complementary ways of knowing (Jessen et al., 2022). Western science and traditional knowledge have evolved with two different approaches to knowledge, and one should not be analyzed by using the criteria of the other (Mazzocchi, 2006). Moreover, indigenous knowledge can also contribute to an understanding of the nature of western science by viewing it as a way of thinking, rather than a "body of knowledge." Sustainability issues are complex and lack absolute answers, requiring both values and knowledge as the foundation for decision-making. Addressing these multifaceted questions involves critically examining various perspectives. In a pluralistic and democratic society, high-quality critical thinking skills are essential for validating the significant choices that need to be made (Davies and Barnett, 2015). Indigenous knowledge also provides a holistic entry that can contribute to a broader view of the world and understanding of the role that society and culture have for western science (Ogegbo and Ramnarain, 2024; Zidny et al., 2020).

The most frequent words in the text including all answers to the open question about challenges were "knowledge," "topic," "time," "little," "difficult," "nature," "survival" and "science" (Figure 5). In Figure 5 the size of the words is proportional to their relative frequency in the text made by pooling together all answers to the open question about challenges associated with teaching Sámi traditional knowledge. These results support the ones from the qualitative analysis because we can see that there is a correspondence between the most frequent words and the categories obtained by the thematic analysis.

4 Conclusion

We conclude that science teacher educators in Norway express valuable insights into how Sámi traditional knowledge can contribute to sustainable development, even though teaching these related subjects can be challenging. Embracing a Two-Eyed Seeing approach could foster a shared understanding among educators and enhance multiple dimensions of sustainability by promoting critical thinking, reflecting on resource use and perspectives on nature, while also promoting decolonization and

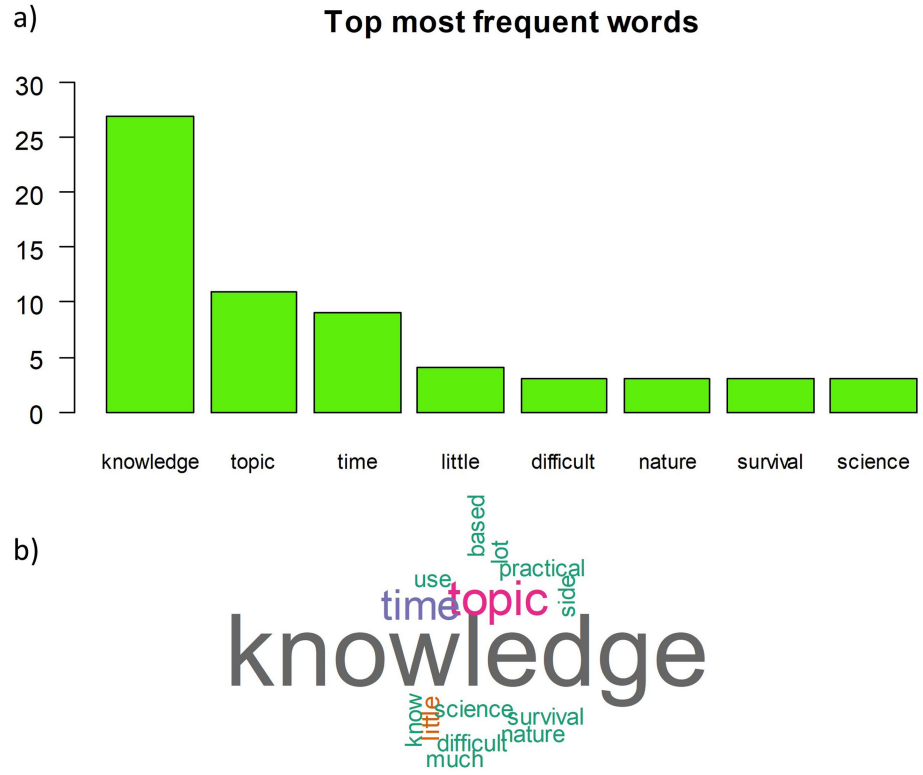

FIGURE 5
(A) Plot showing the eight most frequent words and **(B)** word cloud based on words used at least three times by respondents to answer the question about which challenges do they experience teaching about Sámi traditional knowledge in science education (number answers = 23).

inclusion of the Sámi people. This paper can contribute to creating awareness on the need of better implementing the policy and practice about integration of Sámi themes in science teaching. This could for example be done by promoting further education for science teacher educators, building a network of knowledge bearers that could be invited in the teacher courses, or reevaluating the courses content to make place for Sámi themes.

Data availability statement

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

Ethics statement

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

CM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MK: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Funding acquisition. EM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, 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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