Check for updates

Received: 8 July 2024 | Revised: 20 November 2024 | Accepted: 4 December 2024

DOI: 10.1002/tea.22021

RESEARCH ARTICLE

JRST | WILEY

Science teachers' views on student competences in education for sustainable development

Tuba Stouthart | **Dury Bayram** | **Jan van der Veen**

Department of Applied Physics and Science Education, Eindhoven University of Technology, Eindhoven, The Netherlands

Correspondence
Tuba Stouthart, Department of Applied Physics and Science Education, Eindhoven University of Technology, Building 23, Cascade, Room: 3.17, PO Box: 513, 5600 MB Eindhoven, the Netherlands.
Email: t.stouthart@tue.nl

Funding information
Nederlandse Organisatie voor Wetenschappelijk Onderzoek, Grant/Award Number: 40.5.22395.002

Abstract

In this study, Q methodology was used to identify 16 secondary school physics, chemistry, and biology teachers' views on competences in education for sustainable development (ESD). Our data collection instrument was grounded in the *GreenComp* competence framework developed by the European Commission. We captured three different viewpoints through by-person factor analysis. The largest group, with nine science teachers, prioritized promoting evidence-based instruction while avoiding the political, ethical, or value-laden dilemmas inherent in sustainability issues. While they advocated addressing *critical thinking* and *system thinking*, their reasons for avoiding the dilemmas varied. Some teachers feared that addressing such dilemmas might lead to preaching their own values to students, while others felt unprepared or believed that science should remain objective and value-free. The second largest group, with four science teachers, emphasize *promoting nature* and its well-being above all other competences. Unlike the dominant group, this group of science teachers held themselves responsible for encouraging students to care for nature and to change their attitudes to behave more

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2025 The Author(s). *Journal of Research in Science Teaching* published by Wiley Periodicals LLC on behalf of National Association for Research in Science Teaching.

sustainably. The third group of teachers stood out by advocating fostering *collective action* in science education. While all teachers agreed on the importance of promoting foundational scientific knowledge, they also agreed on excluding politics from science education. This stance was influenced by internal factors, such as their perception of science as empirical, their perceived role as transmitters of scientific knowledge, and a lack of expertise. In total, 12 out of the 16 teachers who participated in our study suggested that subjects such as history are more suitable for addressing certain ESD competences. Additionally, external factors, such as the role of parents and assessments, were cited as potential reasons to dismiss certain ESD competences in science education.

KEYWORDS

Q methodology, education for sustainable development (ESD), competences

1 | INTRODUCTION

Various stakeholders have been working to integrate sustainability concepts into education, recognizing the pivotal role education plays in fostering both sustainability and sustainable development (Bianchi, 2020; Jickling & Wals, 2008). Scholars and policies concerning education for sustainable development (ESD) have emphasized the importance of students' development of cognitive, socio-emotional, and behavioral competences, agreeing on the need to integrate sustainability issues in education (OECD, 2023; Sund & Gericke, 2021; UNESCO, 2020; Wiek et al., 2011). However, despite these advancements in policies and the literature, a lack of consensus on the competences to be addressed in ESD has been identified as a barrier that hinders teachers' ability to enable their students to acquire the necessary competences (Bianchi, 2020; Redman & Wiek, 2021). Moreover, much of the literature focusing on students' competence development comes from higher education (Rieckmann, 2012; Wals, 2014). Previous research findings have also revealed a disconnect between existing theoretical frameworks related to competences in ESD and teachers' views (Cebrián & Junyent, 2015). It has been argued that only highly motivated teachers and teacher-trainers would make the effort to consider frameworks developed outside their disciplines (Stables & Scott, 2002). It is well-known that any policy or framework imposed from outside teachers' own discipline that does not take their views into account is prone to failure (Borg et al., 2012; Fullan, 2015). Therefore, we aim to contribute to bridging the gap between the ESD competences elaborated in research and policy documents, and teachers' views about these competences in the context of secondary school physics, chemistry, and biology education.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Previous research has revealed that even the best-intended professional development efforts focusing on eliminating barriers that science teachers encounter in implementing changes based on reform-oriented goals often fail to address their existing views (Johnson, 2006). To empower secondary school science teachers as successful facilitators of ESD, this study seeks to identify which competences science teachers consider important for their students to acquire in their lessons. We believe it is necessary to understand where science teachers stand regarding the competences identified for learners in policy documents. Understanding these views can help ensure that educational changes are effectively implemented in practice, because it can aid science-teacher educators and professional development designers in incorporating science teachers' views into their programs. In an effort to bridge the gap between policy, research, and practice, this study aims to answer the following research questions:

- What are secondary school science teachers' views on student competences in ESD?
- On what basis do science teachers prioritize or dismiss these competences in their lessons?

1.1 | Theoretical background

1.1.1 | Education for sustainable development: Policy and research

ESD equips learners of all ages with knowledge, skills, values, and attitudes to promote a sustainable future, emphasizing well-being, social justice, cultural diversity, human development and the health of the planet (Mulà & Tilbury, 2023). Promoted by UNESCO, ESD addresses not only the cognitive dimension of learning, but also the socio-emotional and behavioral dimensions (UNESCO, 2020). Integrating ESD into certain subjects or creating stand-alone subjects that address sustainability but remain disconnected from the mainstream curriculum has been criticized as inadequate for equipping students with the competences needed for ESD (Annan-Diab & Molinari, 2017). Despite the ongoing development of policy statements and frameworks, sustainability education has remained limited in science education (Stevenson et al., 2015). To guide policymakers and educators, a Green School Quality Standard was developed to prepare learners to be climate-ready by 2030 (UNESCO, 2023). This standard emphasizes students' participation in climate action both within and beyond the classroom. Moreover, a whole-school approach to ESD has been identified as an effective means to transform educational institutions in the direction of sustainability, with building teachers' capacities as a key element in this approach (Mathie & Wals, 2022).

In alignment with these objectives, the Organization for Economic Co-operation and Development (OECD) considers educational institutions crucial for fostering equitable and sustainable societies (OECD, 2023), reflecting the importance of justice-oriented science education as highlighted in recent literature (Kayumova & Dou, 2022). Moreover, according to the *PISA 2025 Science Framework*, "a scientifically educated person can engage in reasoned discourse about science, sustainability and technology to inform action" (OECD, 2023, p. 9). In this framework, environmental awareness, concern, and agency are considered as key outcomes of secondary school science education, highlighting the importance of equity, justice, and student agency in promoting sustainable practices (OECD, 2023). For example, one outcome for secondary school students is "A concern for the environment and sustainable living and the issues of equity and social justice they raise" (OECD, 2023, p. 35).

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Despite the influence of organizations such as UNESCO or the OECD in shaping educational policy, the extent to which science teachers align themselves with these goals is a subject for research. Policies often overlook research findings, creating a disconnect between policy and practice (Fensham, 2009). In the Netherlands, for example, where this study was conducted, the Foundation for Curriculum Development (SLO) has emphasized integrating sustainability issues with societal implications in secondary school curricula, highlighting the need to equip secondary school students not only with knowledge and skills, but also with values and attitudes regarding sustainability (SLO, 2024). However, research set in the Netherlands has revealed that science teachers struggle with integrating societal issues in their lessons (Harskamp et al., 2021), and Dutch secondary school students are often not used to discussing dilemmas in science lessons (van der Leij et al., 2023b). Therefore, while policies regarding curriculum development emphasize the importance of integrating sustainability issues in science education, research findings revealing the barriers teachers and students face are overlooked. Moreover, a recent study showed that policy experts, practitioners, and scientists in the area of ESD differ in terms of the importance of certain competences to be addressed in secondary school education (Günther et al., 2024). While practitioners and policymakers highlighted the acquisition of value-related competences by secondary school students, this type of competence was underrepresented among the scientists. This discrepancy highlights the need for bridging the gap between research, policy, and practice regarding the views held by science teachers and their reasoning when it comes to student competences in ESD.

The emphasis on ESD in science education is evident in the agendas of professional research organizations such as the National Association for Research in Science Teaching (NARST) and European Science Education Research Association (ESERA). NARST's, 2024 conference theme underscored the importance of equipping all students with the scientific understanding necessary to address sustainability issues, while ESERA highlighted integrating cultural elements in science teaching (ESERA, 2024; NARST, 2024). This reflects a broader trend in science education policy and research: moving beyond merely preparing students to become scientists and toward embracing the socio-emotional dimensions of science learning. By incorporating social, cultural, and ethical considerations, this trend acknowledges the need for an interdisciplinary approach to addressing sustainability issues (Schipper et al., 2021). While contemporary secondary school education typically follows a monodisciplinary approach, the urgency of sustainability issues requires integrated, interdisciplinary approaches (Ming et al., 2023; van den Beemt et al., 2020). However, to successfully implement ESD in science education, we need to better understand the extent to which science teachers' views align with the ESD competences that require them to adopt an interdisciplinary approach to teaching.

1.1.2 | Student competences in ESD

Up to this point, we have used the term *competence* (plural: competences) without distinguishing it from the term *competency* (plural: competencies). It is important to establish the distinction and justify our choice to use *competence*, since these terms are used differently across various contexts (Vare et al., 2022). According to Hyland (1994), *competence* often refers to a broader capacity or overall ability to fulfill roles, whereas *competency* is more narrowly used, referring to a specific skill. For this reason, we have adopted the term *competence* to refer generally to knowledge, skills, values, and attitudes within the context of ESD. However, it is

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

important to stress that a balanced approach that integrates both broad competences and specific competencies is crucial in educational frameworks.

One major challenge educators face today is empowering individuals to navigate sustainability issues (Wals et al., 2014). For this reason, researchers and teacher education institutions have collaborated to identify key competences in ESD. For example, UNESCO identified competences for secondary school students (Rieckmann, 2017). However, according to policy experts in ESD and practitioners of ESD, that framework failed to recognize the competence concerning the ability of students to engage in politics when it comes to sustainability (Günther et al., 2024). The framework developed by the European Commission, on the other hand, provides a more holistic set of sustainability competences for all learners, namely, the *GreenComp* competence framework (Bianchi et al., 2022). According to Bianchi et al. (2022, p. 12), "A sustainability competence empowers learners to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains ecosystem health and enhances justice, generating visions for sustainable futures." The *GreenComp* competence framework was based on a systematic literature review conducted by Bianchi (2020), in which the most influential literature on ESD competences (i.e., Brundiers et al., 2021; Wiek et al., 2011, 2016), the OECD *Learning Compass for 2030* (OECD, 2019), and pedagogies related to sustainability (Sipos et al., 2008) were taken into consideration. The framework is regarded in the literature as having a significant impact on science education curricula and teaching methods across Europe (Laherto et al., 2023). Therefore, the *GreenComp* competence framework provides practical guidance for teachers, as it focuses on learners' acquisition of ESD competences. The competences covered in the *GreenComp* competence framework are shown in Table 1.

The *GreenComp* competence framework consists of 12 competences, grouped into four areas: "embodying sustainability values" (in orange), "embracing complexity in sustainability" (in blue), "envisioning sustainable futures" (in yellow), and "acting for sustainability" (in green). Each competence area consists of three specific competences. For instance, under the area of "acting for sustainability" (in green), the competences are *political agency*, *collective action*, and *individual initiative*. The color-coding is used throughout this manuscript to enhance understanding, particularly in the figures and tables in Section 3.

The extent to which science teachers are aware of this framework or agree with implementing these competences as learning objectives is unknown. Although policies aim to translate principles into effective classroom practices, they often do not consider subject-specific contexts, even though research has indicated that policies developed outside teachers' own disciplines are unlikely to succeed in promoting ESD (Borg et al., 2013). While the frameworks

TABLE 1 *GreenComp* competence framework (Bianchi et al., 2022).

1. Embodying sustainability values	2. Embracing complexity in sustainability	3. Envisioning sustainable futures	4. Acting for sustainability
1.1. Valuing sustainability	2.1. Systems thinking	3.1. Futures literacy	4.1. Political agency
1.2. Supporting fairness	2.2. Critical thinking	3.2. Adaptability	4.2. Collective action
1.3. Promoting nature	2.3. Problem framing	3.3. Exploratory thinking	4.3. Individual initiative

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

that aim to facilitate the implementation of ESD call for cross-curricular or multi-disciplinary approaches, secondary school teachers are trained in a monodisciplinary approach (Stables & Scott, 2002). Therefore, the implementation of ESD in secondary schools remains challenging for teachers, despite being on the political agenda. One reason behind this struggle is that policies do not consider teachers' views, beliefs, and understanding of reform-oriented goals, which critically influence their uptake of educational changes (Fullan, 2015; Haney et al., 1996; Spillane, 1999). Teachers' levels of the necessary knowledge and skills alone do not explain why reform-oriented goals fail in practice (Ryder & Banner, 2013). In other words, it is not only teachers' knowledge that affects their ability and capacity to facilitate ESD, but also their views, perceptions, and attitudes (Chen & Xiao, 2021; Jegstad et al., 2018). To successfully translate policies into classroom practices, we need deeper insight into how teachers perceive these intended educational changes, such as the implementation of ESD. For effective professional development and change in practice, science teachers should be provided with opportunities to share their views and reflect on them, rather than solely having their pedagogical content knowledge or instructional resources be addressed (Gray & Bryce, 2006; Johnson, 2006; Lee & Yang, 2019). Before attempting to build the capacities of science teachers as ESD facilitators, it is crucial to uncover their existing beliefs. These beliefs significantly influence the extent to which they benefit from professional development and integrate new beliefs into their existing belief systems (Kilinc et al., 2017).

1.1.3 | Science education and ESD

The literature has identified three visions characterizing the purposes of science education, where each vision provides the basis for a different orientation for science education that would develop the students in that direction (Roberts, 2007; Roberts & Bybee, 2014; Sjöström et al., 2017). While Vision I focuses mainly on learning about scientific content and its processes for later application, Vision II focuses on learning that fosters participation in decision-making by understanding science and its applications (Roberts, 2007; Roberts & Bybee, 2014). Vision III, on the other hand, incorporates societal science-related issues, including political, economic and ethical considerations (Sjöström et al., 2017). Therefore, while Vision II focuses on context-based science education, Vision III takes it a step further by incorporating value-laden dilemmas in science education (Sjöström et al., 2017). Successful implementation of ESD requires science teachers to adopt Vision II and Vision III. However, research has revealed that science teachers struggle with implementing the use of societal issues in their classroom (Harskamp et al., 2021; Jegstad et al., 2018; Karaarslan & Teksoz, 2016; Kinskey & Zeidler, 2021), especially when it comes to integrating values and ethics (Kim, 2024; Sadler et al., 2006; Tuncay-Yüksel et al., 2023; van der Leij et al., 2023a).

One factor contributing to the challenges science teachers face in implementing ESD may be their teaching approach, which often presents science as a rigid body of theories and rules (Borg et al., 2012; Bossér et al., 2015; Levinson & Turner, 2002; van Driel et al., 2001). Even though the importance of argumentation and discussion in science education has been highlighted in the research (Charro, 2020; Kilinc et al., 2017; Zeidler et al., 2005), science teachers tend to focus on presenting well-established facts that are widely accepted, and not subject to debate (Day & Bryce, 2011). They believe that providing students with well-established scientific information is likely to motivate them to take action for sustainability (Levinson & Turner, 2002; Sund & Gericke, 2020). Although moral reasoning is considered one

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

of the purposes of science education (Roberts & Bybee, 2014; Zeidler & Sadler, 2011, 2023), science teachers consider sustainability issues merely as engaging ways to present scientific knowledge (Tidemand & Nielsen, 2016). Traditional science education and its epistemological stance are founded on conventional disciplinary characteristics such as objectivity and value-free truth, which are inadequate for addressing the value-laden nature of sustainability issues (Laherto et al., 2023; Stevenson et al., 2015).

Similar to the positioning of the purposes of science education according to three visions, recent research has shown that science teachers can be divided into two groups, with significantly opposing views on the inclusion of values in science education (Nordqvist & Jidesjö, 2023). Experienced science teachers are more likely to avoid value-related topics compared to their less experienced counterparts. Once science teachers gain experience and develop a profound appreciation for the nature of scientific knowledge, they are often more reluctant to address the controversial aspects inherent in sustainability issues (Witz & Lee, 2009). This suggests that a deeper shift in epistemic beliefs may be necessary for science teachers to become successful facilitators of ESD (Day & Bryce, 2011; Lee & Yang, 2019; Zeidler et al., 2011).

Despite teacher education for ESD being considered as an emerging research field (Fischer et al., 2022), there is still a significant gap in addressing what science teachers perceive to be important when facilitating ESD. A study conducted in Sweden revealed that science teachers' content choices when implementing ESD differed based on what they perceived as important for their students (Forsler et al., 2024). While some science teachers found it important to stimulate students to act at an individual level and in global cooperation, others focused on students' decision-making on democratic issues in their science lessons. This indicates that science teachers' views significantly impact their teaching practices for sustainability. Additionally, among other factors such as teachers' gender, age, or type of school they work at, the literature has revealed that teachers' subject area is the most important factor explaining their contribution to ESD (Uitto & Saloranta, 2017).

Implementing sustainability issues and addressing ESD requires teachers to adopt interdisciplinary thinking, personal values, and ethical considerations (Zeidler et al., 2019). However, a longitudinal study on the impact of teachers' professional development reported that teachers have low self-efficacy in dealing with economic, political, and international aspects of sustainability issues (Boeve-de Pauw et al., 2022). Science teachers often do not feel confident discussing the controversial aspects involved in sustainability issues (Chen & Xiao, 2021). Science education curricula are dominated by cognitive science categories, such as scientific practices and scientific knowledge, whereas social-institutional categories such as social values and political power structures are hardly ever present (Kaya et al., 2024). Moreover, science education curricula and textbooks often fail to incorporate a political perspective on sustainability issues (Dunlop et al., 2024).

2 | METHOD

2.1 | Research design

This study aims to explore secondary school science teachers' views on student competences in ESD, and the basis on which science teachers prioritize or dismiss these competences in their lessons. To answer our research questions, this study uses Q methodology, which enables researchers to study a person's viewpoints, opinions, beliefs, attitudes, and the like

(Brown, 1996). Q methodology has been identified as an emerging method in educational research to sort out subjectivity (Lundberg et al., 2020). While it combines both qualitative and quantitative research techniques, Q methodology aims at clustering the participants based on their standpoints rather than aiming at reaching a statistical representation of the target group. This method explores how participants' perspectives about the phenomenon being studied vary, or the level of agreement across them.

Given the exploratory nature of our research questions, Q methodology offers an effective research design to capture science teachers' views on student competences in ESD. Although the literature has identified three visions characterizing the purposes of science education (Roberts, 2007; Roberts & Bybee, 2014; Sjöström et al., 2017), it remains unclear on what basis science teachers prioritize or dismiss specific student competences in ESD. Following Q methodology, we asked our teacher participants to rank-order the relative importance of statements based on the *GreenComp* competence framework, rather than rating each statement independently. This forced-choice aspect of Q methodology compelled participants to make relative comparisons among the statements, allowing us to explore science teachers' underlying priorities and uncover distinct viewpoints. Despite our small sample size of 16 science teachers in the Netherlands, the by-person factor analysis in Q methodology enabled us to examine the degree of alignment in participants' views, revealing areas of consensus and controversy among teachers' views.

2.2 | Q-set design and content

The data collection instruments used in Q methodology consist of a set of statements, called a Q set. All Q-methodological studies require data collection in the form of Q sorts, where the participants are asked to rank-order the statements into a quasi-normal distribution, from most agree to most disagree. It is different from most other methods, since it requires the participants to rank a set of statements relative to one another (Watts & Stenner, 2012). Most of the time, the Q-sort activity is followed up by a semi-structured interview where participants are asked to elaborate on their ranking for the statements they agree and disagree with most strongly. Instead of capturing participants' views by using the individual statements, Q methodology allows the researchers to capture a holistic overview and the relationships between the statements. This holism of Q methodology is considered as one of its strongest characteristics when it comes to studying participants' views (Watts & Stenner, 2012). Through sorting the statements, each participant provides a model of their viewpoint on the issue under study. The subsequent intercorrelation and by-person factor analysis of each participant's Q sort allow the researchers to identify existing views on the phenomenon being studied.

Our Q set consisted of 36 statements grounded in the *GreenComp* competence framework developed by the European Commission (Bianchi et al., 2022). To comprehensively capture the essence of the *GreenComp* competence framework in our Q set, we developed three statements for each of the 12 competences, spanning the knowledge, skill, and attitude dimensions, a total of 36 statements. Our Q set is shown in Table 4 in Section 3.

The development of our Q set involved two test-runs aimed at refining the statements for clarity and relevance. These test-runs were conducted to ensure that the statements aligned with the competences outlined in the framework and were easily understandable by our target participants: secondary school science teachers, many of whom were presumed to be non-native

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

English speakers, given the study's context in the Netherlands. It is important to note that our Q set was presented in English to all participants.

The first test-run involved discussions with seven PhD candidates in educational sciences. The PhD candidates varied in terms of their experience in educational sciences, from 1 to 30 years, 11 years of experience on average. This consultation involved comparing each statement with the corresponding competence in the *GreenComp* competence framework to ensure alignment. As a result, modifications were made to enhance understanding. For example, knowledge-related statements were revised to begin with "knows..." and skill-related statements with "can...," resembling learning objectives recognizable to secondary school teachers.

In the second test-run, four secondary school science teachers engaged in the Q-sort activity and post-sorting interview. Two of the teachers taught biology, one physics, and one chemistry, with teaching experience ranging from 2 to 27 years. They were initially asked to sort the 36 statements as agree, disagree, or neutral, indicating whether they viewed the competence addressed in each statement as important to implement in their lessons to facilitate student acquisition of it. Following this sorting activity, they were asked to rank the statements based on their level of agreement into a forced, quasi-normal distribution grid, shown in Figure 1. In this grid, the statements can be positioned according to the rankings, ranging from −5 to +5 horizontally, with +5 indicating the strongest agreement with a statement, −5 indicating the strongest disagreement, and 0 denoting neutrality. Notably, vertical positioning in the grid does not imply a hierarchy.

During this pilot study, we observed that teachers tended to group statements together based on similar terminology used in their wording. To address this, we revised the statements to avoid using comparable terms, ensuring that teachers did not perceive them as having similar meanings and thus ranked them close together. Furthermore, this pilot study informed us about the approximate duration of both the Q sort and the post-sorting interview, aiding our preparation before recruiting actual participants for the study.

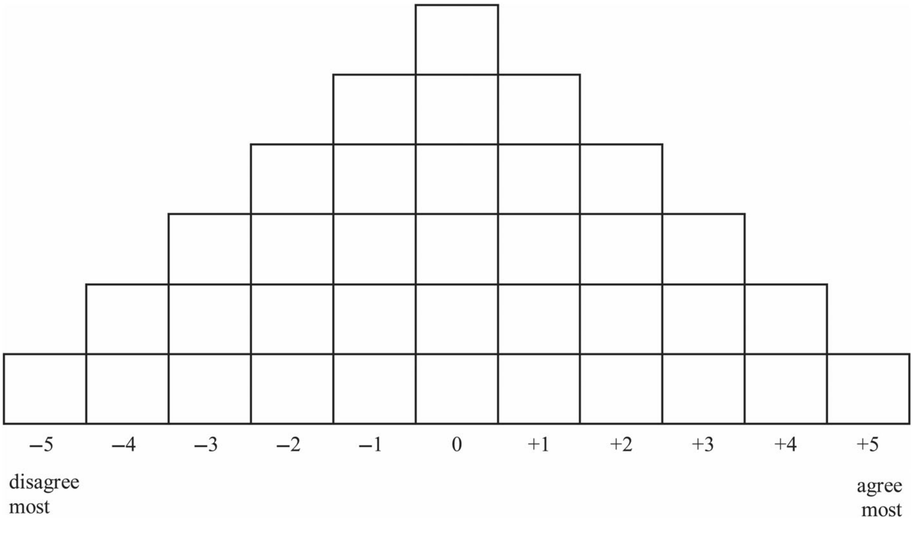

FIGURE 1 Distribution grid used for the study.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

2.3 | Participants

Secondary school science teachers from the authors' network participated in this study between September and December 2023. Sixteen secondary school teachers whose main subject was physics, chemistry, or biology took part in this study. Demographic data for the participating teachers can be seen in Table 2 below.

TABLE 2 Demographic data for the participating teachers.

Teacher No.	Main subject	Other subject(s)	Year of experience	Age (years)	School type	Upper/lower secondary education
1	Physics	Nature, life and technology	1	56	Dutch	Upper
2	Physics	Sports	5	27	Bilingual	Both
3	Physics	-	8	29	Dutch	Lower
4	Physics	Chemistry	10	31	Bilingual	Lower
5	Physics	-	18	44	International	Upper
6	Chemistry	-	11	56	Dutch	Both
7	Chemistry	History	12	32	Dutch	Both
8	Chemistry	Biology	13	42	International	Both
9	Chemistry	-	15	39	Dutch	Upper
10	Chemistry	-	17	54	Dutch	Upper
11	Chemistry	-	20	53	International	Upper
12	Biology	Big history	2	38	Bilingual	Upper
13	Biology	Environmental systems and societies, geography	4	27	International	Upper
14	Biology	Global perspectives, sciences	9	46	Bilingual	Both
15	Biology	Environmental systems and societies	18	47	International	Upper
16	Biology	Environmental systems and societies, sciences	21	45	International	Both

Note: School types are classified into three: Dutch schools follow the Dutch education system in Dutch language, bilingual schools follow the same system with some classes in English language, and international schools follow the International Baccalaureate curriculum.

We identified the type of school at which each of our participating teachers taught in Table 2 based on three different school types. Dutch schools follow the Dutch education system and deliver their curriculum entirely in the Dutch language, while bilingual schools follow the same system but offer some classes in English language. In contrast, international schools provide education in the English language, following the International Baccalaureate (IB) curriculum. As shown in Table 2, some of our participating teachers taught other subjects besides teaching physics, chemistry, or biology as their main subject. For example, Big History

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

and Global Perspectives are interdisciplinary subjects offered at bilingual schools in the Netherlands, integrating various fields such as geology, biology, and history to encourage students to think critically about global issues and understand their complexities. Nature, Life, and Technology (translated from the Dutch) is another interdisciplinary subject offered at Dutch schools, combining elements from the sciences, mathematics, and technology. Environmental Systems and Societies is also an interdisciplinary subject that integrates the sciences and humanities offered as part of the IB curriculum. We consider our inclusive approach that involves physics, chemistry, or biology teachers working at different types of schools, with some also teaching additional subjects, to be effective for capturing a broader range of views, particularly given the exploratory nature of our study.

2.4 | Data analysis: Administering the Q sort

We used paper version of the statements and the distribution grid shown in Figure 1 for the Q-sort activity. Prior to sorting, the participants were introduced to the *GreenComp* competence framework and the quasi-normal distribution grid. They were asked to think aloud while sorting and ranking, which allowed the researcher to capture their thinking and reasoning through audio-recording. They were informed that the researcher would remain silent during the Q sort, taking notes only for clarification during the post-sorting interview. This approach allowed participants to interpret statements independently. Additionally, showing them the post-sorting interview questions beforehand enabled participants to elaborate on their reasons while ranking, reducing the time needed for the interviews.

The participants were asked to rank-order the statements using the forced-choice, quasi-normal, and symmetrical distribution grid shown in Figure 1. They were asked to rank their level of agreement with the importance of the competence addressed in each statement from their standpoint as a science teacher, considering the main subject they teach. Agreeing with a statement meant that "I agree that it is important for my students to acquire this competence through my teaching of physics, chemistry, or biology." The sorting and ranking activity, which lasted approximately 30 minutes, was followed up by a semi-structured interview, also taking approximately 30 minutes. The semi-structured interview questions, such as "Why do you think this [the one ranked at +5] is the most important competence?", aimed to capture participants' rationales for their agreement or disagreement with the importance of the competences mentioned in the statements ranked at the extremes. It is important to note that the interviews took place in English, with participants occasionally using Dutch words. In such cases, they were prompted to clarify the meaning of these words.

2.5 | Statistical analysis

Statistical analysis in Q methodology consists of three methodological transitions. These transitions are detailed in the following sections.

2.5.1 | From Q sorts to factors

A total of 16 Q sorts were entered manually in an Excel sheet. The data were later intercorrelated and factor-analyzed using a dedicated software package called Ken-Q Analysis Desktop

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Edition (KADE), version 1.2.1 (Banasick, 2019). Seven factors were extracted using centroid factor analysis (Brown, 1980), and we chose to keep the first three factors for factor rotation. At this stage, we followed the Kaiser-Guttman criterion (Guttman, 1954; Kaiser, 1960) and looked at the eigenvalues of each factor. According to this criterion, factors having eigenvalues lower than 1.00 account for less variance in the dataset than a single Q-sort. For this reason, we kept the first three factors for rotation, which had eigenvalues of 5.25, 1.26, and 1.18, respectively, cumulatively explaining 48% of the variance. All the other factors extracted using centroid factor analysis had eigenvalues less than 0.80, according to KADE software.

After deciding to keep the first three factors for rotation, we used both varimax and judgmental rotation, where participants' loadings on a factor are considered to be defined automatically by the software based on the similarities in their sorting patterns. For example, as a result of factor rotation, nine teachers loaded significantly on a single factor, meaning that compared to other teachers, their sortings of 36 statements were statistically similar. Therefore, loading together on a particular factor suggests they have remarkably similar views relative to the phenomenon studied (Watts & Stenner, 2012).

2.5.2 | From factors to factor arrays

While a factor in Q methodology represents a cluster of participants with shared viewpoints, a factor array is a hypothetical Q-sort that represents the viewpoint reflected in a specific factor (Watts & Stenner, 2012). A factor array shows how a hypothetical participant would have ranked all of the statements to represent a factor. Even though each participant has a unique Q-sort, when they load significantly on a factor, they exemplify the views captured in that factor, showcasing similar views within the identified theme. By using the KADE software, we grouped the Q sorts of teachers who loaded significantly on a factor to form a single, prototype Q-sort for each factor, called a factor array. Each factor array is generated with higher loading exemplars being given more weight in the process, since they better exemplify the factor. To illustrate, the Q sorts from the nine teachers who loaded on a single factor were merged via the software, which created a prototype Q sort representing the views captured in that factor, namely, Factor 1.

2.5.3 | From factor arrays to factor interpretations

The aim of factor interpretation is to understand and explain the views captured by the factor arrays. For this, we first looked at how each factor array's views were positioned across the four *GreenComp* competence areas. We had nine statements for each *GreenComp* competence area. Therefore, looking at the sum of the levels of importance attributed to these nine statements allowed us to present our data in a radar chart, shown in Section 3. This visualization allowed us to compare the views in the factor arrays to gain insights into differences and similarities before we analyzed the views captured in each factor array in depth.

We then continued our analysis with a within-factor interpretation by examining the highest- and lowest-ranked statements within each factor array. We refer to these as statements ranked at extremes, with +5, +4, +3 as the highest-ranked statements, and −3, −4, −5 as the lowest-ranked. Looking at the statements ranked at extremes is a step toward within-factor interpretation in Q methodology, because these statements' rankings deviate most from the distribution mean (Watts & Stenner, 2012).

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

However, it is not always the statements that are ranked at extremes that define a factor array's views. For this reason, we analyzed the statements that were ranked significantly differently in the factor arrays. Statements are considered as *distinguishing statements* if the rankings given to these statements by participants who loaded on a particular factor differed significantly from the rankings given by all participants who loaded on the other factors (Watts & Stenner, 2012). For our study, we considered statements as distinguishing with $p < 0.01$.

Furthermore, we used the post-sorting interviews to assist our factor interpretation. We used the comments made by the teachers while sorting and their responses to the semi-structured interview questions, which were transcribed verbatim. Analyzing the statements ranked at extremes, the distinguishing statements and the post-sorting interviews allowed us to capture the existing viewpoints of teachers within each factor array in depth.

Our analysis was further enriched with cross-factor interpretation, aiming to capture characteristic statements for each factor array and their overlap. In this way, we were able to identify the areas of consensus and disagreement between and among the factor arrays. Finally, we assigned names to each factor array to effectively communicate the core viewpoints captured within each factor array. Naming factor arrays are considered to provide them with a distinct identity in Q methodology (Watts & Stenner, 2012, p. 160). We used these names as titles to present our findings for each factor array in Section 3.

3 | RESULTS

Our data revealed three factors. Factor loadings were calculated via KADE software according to how similar each teacher's sorting was compared to the others. Table 3 shows factor loadings for our 16 participating teachers. Nine teachers loaded significantly on one factor, Factor 1. The loadings of these nine teachers on Factor 2 or Factor 3 were non-significant, meaning that their views were indeed well-grouped within Factor 1. To highlight the defining loadings, we used three shades of blue as color-coding in Table 3, based on which factor each teacher significantly loaded on. Our second factor, Factor 2, had four teachers who loaded significantly, while the third factor, Factor 3, had three teachers.

TABLE 3 Teachers' factor loadings and contextual characteristics.

Factor loadings					
Factor 1	**Factor 2**	**Factor 3**	**Subject**	**School type**	**Teacher no.**
0.831*	0.196	−0.029	Chemistry	Dutch	9
0.793*	0.192	0.214	Biology+	International	15
0.778*	0.215	−0.045	Physics	International	5
0.740*	−0.226	0.028	Chemistry	Dutch	10
0.681*	0.163	0.194	Chemistry	Dutch	8
0.599*	0.186	−0.264	Chemistry	Dutch	6
0.509*	0.389	0.119	Biology+	Bilingual	12
0.466*	0.018	0.077	Chemistry+	Dutch	7
0.363*	0.329	−0.027	Physics+	Dutch	1

(Continues)

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 (Continued)

Factor loadings					
Factor 1	Factor 2	Factor 3	Subject	School type	Teacher no.
0.298	0.579*	−0.202	Chemistry	International	11
0.527	0.563*	0.014	Biology+	Bilingual	14
0.396	0.554*	0.379	Biology+	International	13
−0.132	0.488*	0.450	Biology+	International	16
0.305	−0.018	0.583*	Physics	Dutch	3
−0.002	−0.302	0.504*	Physics+	Bilingual	2
0.086	0.308	0.343*	Physics+	Bilingual	4

Note: Defining factor loadings are shown by an asterisk (*). Teachers who taught more than one subject are indicated by a plus (+) after their main subject.

According to Table 3, the majority of the teachers who loaded significantly on Factor 1 were chemistry teachers working at Dutch secondary schools. In contrast, none of the teachers who significantly loaded on Factor 2 worked at a regular Dutch secondary school. They worked either at an international or bilingual school. Moreover, three of the four teachers who loaded on this factor taught biology as their main subject, and at least one other subject that was interdisciplinary. Finally, just three physics teachers loaded significantly on Factor 3.

As a result of identifying the exemplar teachers for each factor, prototype Q-sorts, also referred to as factor arrays, were generated via the dedicated KADE software. The result is presented in Table 4, where the Q set used in this study is shown together with the rankings for each factor array on the right-hand side of the table.

TABLE 4 Q set used in this study and the prototype Q-sort values for each factor array.

Statements			Factors 1	2	3
Embodying sustainability values	01	Knows their own sustainability values.	−1	−1	+3
	02	Can identify and compare different sustainability values.	0	+1	0
	03	Acts in line with own sustainability values.	−2	−1	−2
	04	Knows that ethical concepts and justice for current and future generations are related.	−3	+2	−4
	05	Can apply equity and justice to evaluate how current practices affect future generations.	−3	−3	−5
	06	Acknowledges the impact of own behavior on others and future generations to act accordingly.	−2	+3	−3
	07	Knows that our well-being, health, and security depend on the well-being of nature.	−1	+5	0
	08	Can assess one's own impact on nature.	+1	0	+2
	09	Values the quality of nature.	+1	+3	−1
	Sub-score		−10	+9	−10

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 4 (Continued)

Statements			Factors 1	2	3
Embracing complexity in sustainability	10	Knows how different elements and their interactions form a system.	+4	+1	0
	11	Can describe connections and interactions in a complex system.	+3	0	+1
	12	Acknowledges the connections and interactions between natural events and human actions.	+2	+2	−3
	13	Knows sustainability claims need to be supported by evidence.	+4	+4	0
	14	Can evaluate information and arguments.	+5	+4	+2
	15	Develops a critical attitude toward claims.	+3	+1	+2
	16	Knows that sustainability problems are often complex.	+3	−2	−2
	17	Can identify appropriate approaches toward solving sustainability problems.	+1	+1	+1
	18	Listens actively and shows empathy to frame sustainability challenges.	−1	−1	−1
	Sub-score		+24	+10	0
Envisioning sustainable futures	19	Knows the difference between expected, preferred, and alternative futures for sustainability scenarios.	+1	0	−1
	20	Can identify steps that lead to a more sustainable future.	0	0	+2
	21	Is willing to consider alternative future scenarios.	−1	0	0
	22	Knows that some sustainability problems come with uncertainty and risk.	0	−2	−2
	23	Can cope with uncertainty of wicked sustainability problems.	0	−3	0
	24	Is open to alternative solutions in the face of uncertainty.	+1	−1	+3
	25	Knows that sustainability problems must be tackled by combining different disciplines.	+2	+3	−2
	26	Can think creatively, generating different ideas for sustainability.	+2	+2	+5
	27	Is willing to explore new ideas for sustainability.	+2	+1	−1
	Sub-score		+7	0	+4
Acting for sustainability	28	Knows about political decisions concerning sustainability.	−3	−4	−4
	29	Can critically reflect on political responsibility and accountability for a sustainable future.	−4	−5	−1
	30	Encourages effective policies for sustainability.	−4	−3	−3
	31	Knows how to work with others to promote sustainable practices.	−2	−1	+4
	32	Can build a coalition to address sustainability problems.	−5	−4	+1
	33	Is willing to engage with others to challenge the status quo.	−2	−2	+4

(Continues)

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 4 (Continued)

Statements			Factors 1	2	3
	34	Knows one's own potential to contribute to sustainability.	0	+2	
	35	Can reflect on daily habits with respect to sustainability.	0	−2	+3
	36	Is willing to change personal behavior that affects sustainability.	−1	0	+1
	Sub-score		−21	−19	+6

Note: Positive numbers indicate strength of agreement, whereas negative numbers indicate strength of disagreement, from +5 to −5, 0 denoting neutrality.

Table 4 shows the rank associated with each statement in each factor array, the prototype Q sorts. For example, Statement 1 was ranked at −1 in the first-factor array, meaning that even though each participant who loaded on this Factor 1 might have had a different ranking of this statement, when grouping the factor exemplars, the ranking was at −1. The rankings of the statements covering the *GreenComp* competence area of "embodying sustainability values" were at −1, 0, −2, −3, −3, −2, −1, +1, +1 in the first-factor array. In that case, the sum of the rankings for "embodying sustainability values" was −10. We interpreted this as the sub-score for this competence area, which shows the relative level of importance attributed to "embodying sustainability values" in the first-factor array.

Looking at the sub-scores for each *GreenComp* competence area informed the creation of the radar chart shown in Figure 2. This figure allowed us to grasp the positioning of the three-factor arrays in relation to the importance they attributed to the four competence areas identified in the *GreenComp* competence framework. Each factor array's position indicates its overall stance on the importance of the statements that covered these four *GreenComp* areas.

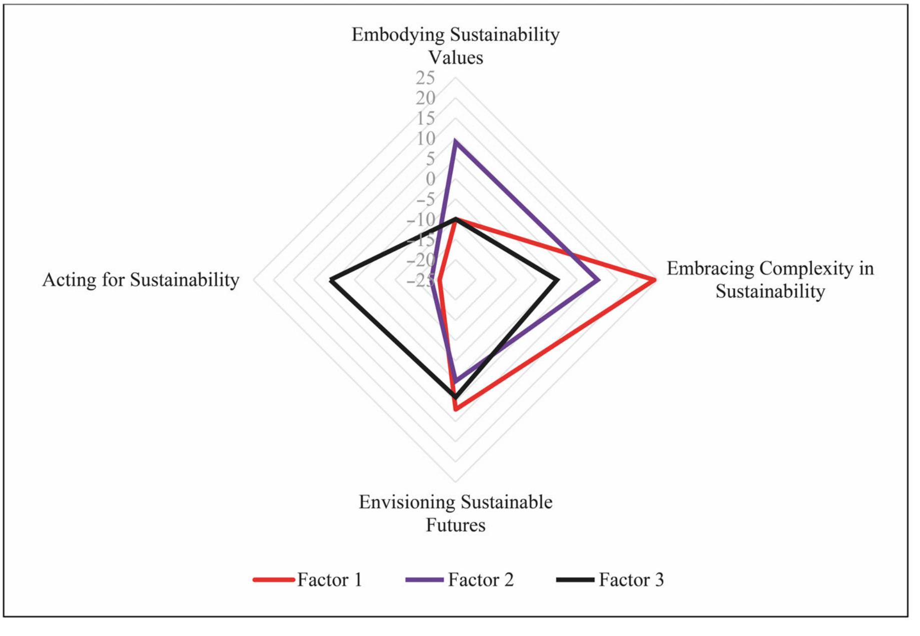

FIGURE 2 Three factor arrays and their positioning according to the *GreenComp* competence areas.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

With regard to the particular factor arrays, Factor 1 is distinguished in this figure from the other two factors by the notable emphasis on statements related to "embracing complexity in sustainability," resulting in the highest sub-score within this competence area. This means that teachers loading significantly on Factor 1 advocated embracing complexity when it comes to implementing competences in ESD. Looking at how Factor 2 is positioned revealed that it stands out thanks to an emphasis on statements associated with "embodying sustainability values." When we looked at the competence area of "acting for sustainability," we saw that teachers loading significantly on Factor 3 assigned more importance to this competence area compared to the other factor arrays. In the case of "envisioning sustainable futures," the factor arrays are positioned closer to one another compared to their positioning in other areas. While this figure allowed us to capture the views of the three factor arrays holistically, the next section explores the views of each factor array in depth. In this section, we use abbreviated notation to refer to a statement; for example, "S1" refers to Statement 1.

3.1 | Factor 1: Promoting evidence-based instruction without political, ethical, or value-laden dilemmas

This factor was the most dominant group with nine teachers, and explained 28% of the variance in the dataset. It consisted of five chemistry, two biology, and two physics teachers. The majority of the teachers (6 out of 9) who loaded on this factor worked at Dutch secondary schools. The highest-ranked statements in this factor array shown in Figure 3 revealed that the most crucial competences were *critical thinking* (S13, S14, S15), *system thinking* (S10, S11), and *problem framing* (S16). The statements shown in this figure are all color-coded in blue, meaning that they belong to the *GreenComp* competence area of "embracing complexity in sustainability," indicating this factor array's alignment with that competence area. Additionally, Statement 10 and Statement 11 have an asterisk, meaning that the ranking of these two statements distinguished this factor array's views from the others. Therefore, this factor array stands out due to the importance attributed to *system thinking* by the teachers who loaded on this factor.

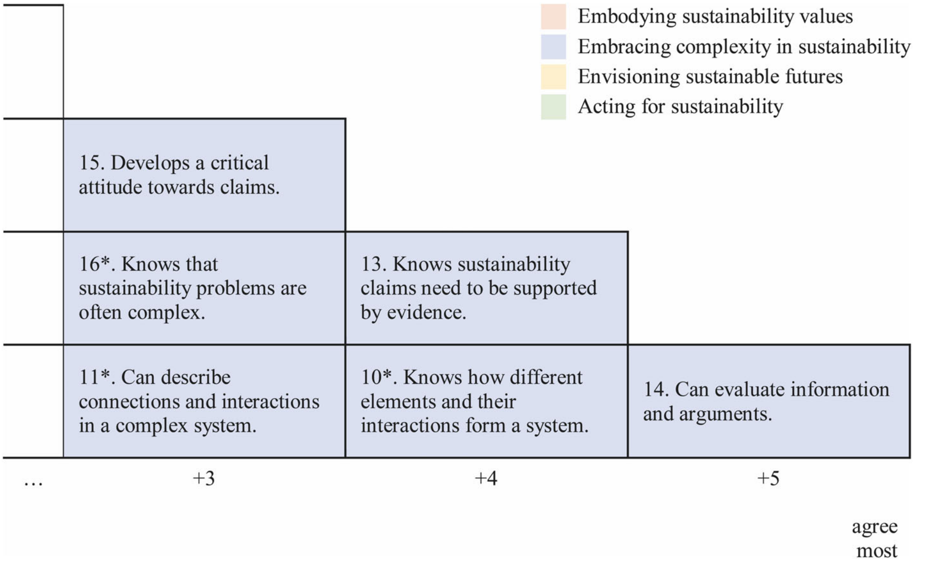

FIGURE 3 Highest-ranked statements by Factor 1, where distinguishing statements are shown by an asterisk.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

In this factor array, the most important ESD competence for learners to acquire in science lessons was to be able to evaluate information and arguments (S14). Teachers who loaded on this factor recognized the importance of fact-checking and supporting claims by evidence when it comes to sustainability issues. They emphasized *critical thinking* as intrinsic to science education, captured during the interviews when Teacher 15 stated that "science is evidence-based" and Teacher 9 expressed that supporting claims with evidence is "the approach of science." According to Teacher 9, acquiring *critical thinking* and *system thinking* competences results in students developing their values and acting on them. He referred to competences addressed in "embodying sustainability values" and "acting for sustainability" as side-goals, which might happen as a result of developing *critical thinking* and *system thinking*.

> Yeah, bijvangst *[Dutch word referring to a byproduct]*, not the main goal, but something that emerges from what I have on the ride. ...I think when you develop the critical attitudes toward claims and sustainability claims need to be supported by evidence, when we teach our children these, the willingness to change and acting in line with your own values can be a side effect.
>
> (Teacher 9, Chemistry)

Even though *critical thinking* was the most important competence in this factor array, what distinguished this view from other factor arrays was the importance attributed to *system thinking*. In this factor array, the importance of knowing how different elements and interactions form a system (S10) was emphasized. According to the teachers who loaded on this factor, equipping learners with the skill to be able to describe connections and interactions in a complex system (S11) is important in science education for implementing sustainability. Teacher 10 hoped that acquiring *system thinking* competences would naturally result in *valuing sustainability* as a competence, similar to how Teacher 9 associated this development with the acquisition of *critical thinking*.

> Describing connections and interactions in a complex system, knowing different elements and their interactions. I think that is the most important thing for chemistry. ...Knowing their own sustainability values and stuff is the least important. Well, it is important, but not for chemistry teaching. I hope that if you teach them about ideas and systems, this will follow, you know, naturally.
>
> (Teacher 10, Chemistry)

The ranking of Statement 16 also distinguished this factor array's view. The importance of understanding the complexity of sustainability issues was highlighted in this factor array. According to Teacher 6, concepts in chemistry are often approached with a binary mindset by students — as being right or wrong. However, when dealing with sustainability problems, such a perspective falls short, and students are required to adopt different viewpoints due to the complexity involved in sustainability issues. Therefore, *problem framing* and *system thinking* were highlighted as essential skills for navigating these complexities.

> In general, pupils in my class think that there is truth and untruth, there is a yes and no, there is a right answer and wrong answer. When you want to solve a problem, you start here, and you end up there. There are a lot of problems that are not linear, but sustainability is not even nonlinear, but complex in many ways. So, I

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

think that it is quite important to know that there are problems that are kind of unsolvable, nonlinear, multidisciplinary.

(Teacher 6, Chemistry)

The lowest-ranked statements in this factor array are displayed in Figure 4. These statements related to two *GreenComp* areas: "acting for sustainability" and "envisioning sustainable futures," which have the color codes of green and orange, respectively. As shown in Figure 4, in this factor array, the least importance was attributed to *collective action* (S32), *political agency* (S28, S29, S30), and *supporting fairness* (S4, S5).

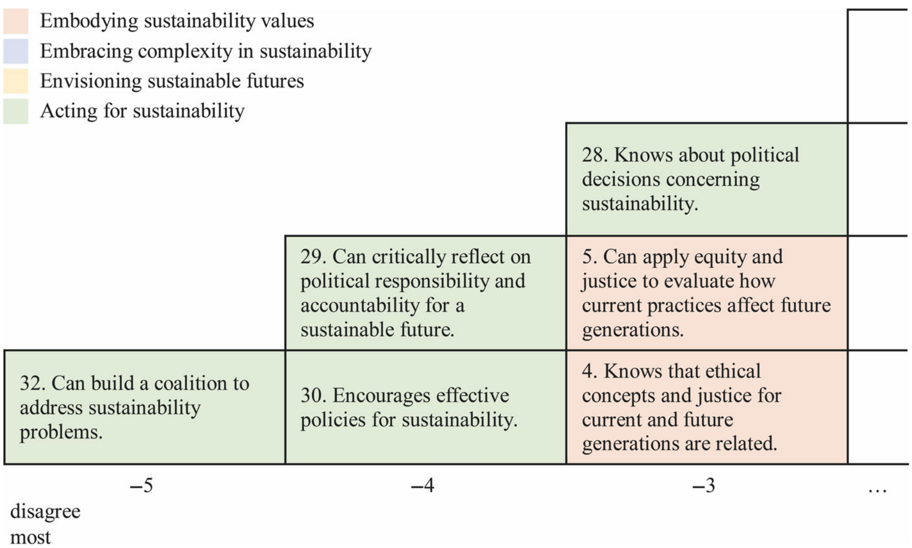

FIGURE 4 Lowest-ranked statements by Factor 1.

All three statements covering *political agency* were ranked among the most disagreed with, indicating that there was little to no emphasis on *political agency* in science education in this factor array. For example, acquiring knowledge about sustainability-related political decisions (S28) was considered a low-priority competence in science education. Teacher 8 thought that for students to acquire the competence to encourage effective policies for sustainability (S30), the teacher should dictate what is right or wrong to do. However, he disagreed with the idea of teachers imposing their own opinions onto students. He referred to this as "playing God." Consequently, he advocated that chemistry education should be neutral when it comes to *political agency*. He felt that he is responsible for providing the students with what information there is, and it is up to the students to form their own views. Otherwise, he would feel as if he were pushing a certain narrative.

...but then again, I am not God, so I am not the one to say what is right or wrong in this. This is more of a political question and for me, chemistry should be apolitical. ... For me personally I feel like I have to give the students the information there is, but it is up to them to form their own opinions with that. So, pushing a certain narrative, yeah, that does not sit well with me, that is the same for any political statement.

(Teacher 8, Chemistry)

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Teacher 9, however, held a different perspective on excluding *political agency* from the science classroom. He expressed a lack of confidence in addressing this competence, going so far as to exaggerate by suggesting he would devote only one sentence to it over 3 or 4 years of chemistry education. Alternatively, he suggested that mentors or other subjects could take on the responsibility of facilitating the acquisition of *political agency*.

> I do not feel confident about teaching my students about politics. …There is a role for the mentor or maybe in subjects like History, or Maatschappijleer *[subject in Dutch secondary school education addressing civic education]*, but in my chemistry education, no. I think in the 3 or 4 years that they have the subject Chemistry, I can spend one sentence on it, and that is enough.
>
> (Teacher 9, Chemistry)

Teacher 6 shared the view that other subjects might be more appropriate for addressing *political agency*. He said that collaboration between chemistry teachers and teachers of philosophy would make it possible to establish connections between chemistry and the political dimensions of sustainability issues. According to him, without such collaboration, implementing this competence is not feasible.

> I find it hard to make connections with chemistry, they are political or philosophical. But of course, there are political and philosophical things in chemistry. And it would be nice for chemistry to work together with philosophy, and then we could pay attention to this, but first we should work together.
>
> (Teacher 6, Chemistry)

Even though teachers who loaded on this factor differed in terms of their reasoning when it comes to leaving politics out of science education, there was a consensus among them that the primary focus in science education should remain on foundational scientific knowledge. Teacher 5, for example, reasoned that he is not the right person to address *political agency*.

> I am not the right person to do that because I do not have the pedagogical content knowledge for that, pedagogical content knowledge for moral education. And I am also not current enough, as in, I do not have time to stay current with the latest developments, for example, in the political realm.
>
> (Teacher 5, Physics)

Teacher 10 preferred to avoid classroom discussions regarding politics because she did not feel well-equipped to navigate discourse that could involve managing students' emotions. She recognized the relevance of addressing societal issues such as the nitrogen crisis in the Netherlands within chemistry education. However, she hesitated to integrate such topics into her lessons, particularly when teaching about the nitrogen cycle, due to politics. Aware of the potential heightened tensions, Teacher 10 chose to maintain a neutral stance in her teaching approach when it comes to societal issues.

> I want to teach them about the nitrogen cycle and about approaches, but I do not go into the politics of that subject because it will take a lot of time in the classroom,

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

> and with a lot of emotions, because of course we have people who live next door to the farmers, where they have a continuous smell of the pig farm, ...and they are neighbors and they sit in my classroom. It is a difficult discussion, and I am not equipped to handle all those emotions. There are too many emotions, I just teach chemistry.
>
> (Teacher 10, Chemistry)

The other two lowest-ranked statements shown in Figure 4 are Statement 4 and Statement 5. These statements cover the competence of *supporting fairness*. Teachers who loaded on this factor argued that concepts of equity and justice are less important to implement in science education. Just as science teachers had different reasons for dismissing *political agency*, they also had varied reasons for ranking the statements related to *supporting fairness* as a low priority. For example, Teacher 1 seemed unsure about how ethics could apply to physics lessons. She viewed discussions on topics such as nuclear energy as involving weighing options rather than making ethical judgments, as both choices may conflict with personal values, but a decision must still be made based on priorities.

> In physics there are topics of course that you can be pro or against, like nuclear energy. But I am not sure if I would call that ethical, because ethical is like almost neutral, this is good and this is not good. It has to do with values. I think debates in physics are more like what you find more important than the other. It is not so much about values, but what you judge higher. ...I think that it is a choice between two bads actually, they are both against your values, but we need energy as well.
>
> (Teacher 1, Physics)

Teacher 15, viewing science as objective and values as inherently subjective, did not incorporate value-related issues into her teaching. According to her, it is students' personal journey to develop values, and not part of the science curriculum. Teacher 15 felt that if she addressed values in class, she would be preaching her own values to the students.

> Values are so subjective, it is a little bit opposite of science almost. ...I think science often tries to take out personal feelings in some cases, and values are so different based on your family, upbringing, ...your religion. To me, science can bring all those things together, but your values are so personal that I do not see them as part of the science curriculum. ...Values are their own thing to develop, so in biology I am not teaching values, I am teaching something a bit broader, and they develop their values as individuals. Otherwise, I am like preaching to them about my values, which is not really the job of a good teacher.
>
> (Teacher 15, Biology)

3.2 | Factor 2: Bridging evidence-based instruction with a commitment to nature's well-being

This factor was the second most dominant group with four teachers loading significantly, and it explained 12% of the variance in the dataset. This factor had one chemistry and three biology teachers, and they worked at either an international or a bilingual secondary school. Analysis

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

of the highest-ranked statements, shown in Figure 5, revealed that in this factor array *promoting nature* (S7, S9), *critical thinking* (S13, S14), *supporting fairness* (S6), and *exploratory thinking* (S25) were prioritized. The statements are color-coded orange, blue, and yellow, meaning that these statements belong to the *GreenComp* competence areas of "embodying sustainability values," "embracing complexity in sustainability," and "envisioning sustainable futures," respectively. Teachers who loaded on this factor recognized the importance of equipping students with the ability to critically assess claims and evidence. However, their primary focus lay in developing an appreciation for the interconnectedness of human well-being, health, and security with the health of the natural world.

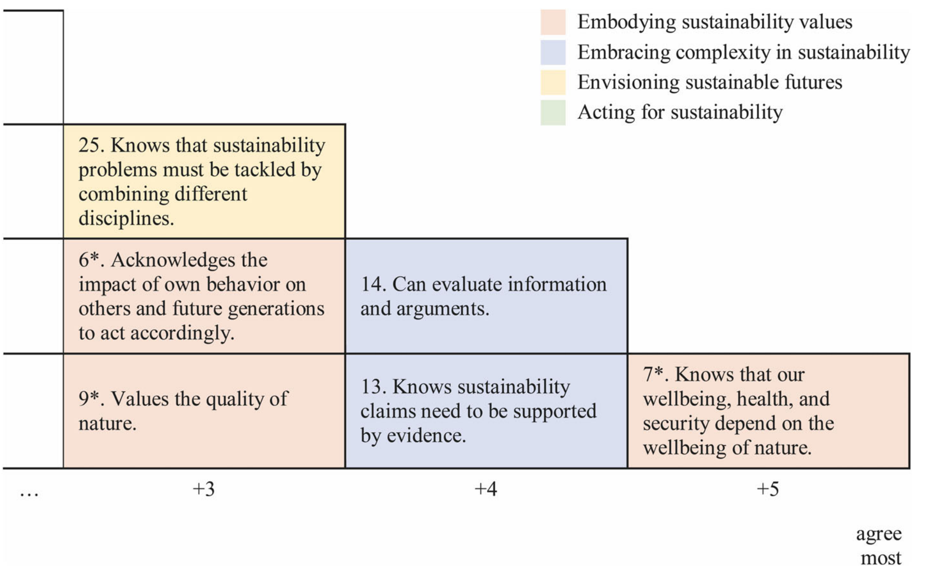

FIGURE 5 Highest-ranked statements by Factor 2, where distinguishing statements are shown by an asterisk.

Three of the most significant competences highlighted in this array revolved around "embodying sustainability values," with the foremost competence being related to *promoting nature*. In this factor array, it was viewed as essential for secondary school students to understand the role of nature before delving into skills such as evidence-based decision-making and evaluating information and arguments. According to the teachers who loaded on this factor, understanding the interconnectedness between human well-being, security and the well-being of nature (S7) is vitally important. According to Teacher 13, establishing this connection should be the primary focus in biology education, as many people lack such a connection to nature. Drawing from her teaching experience in Finland, where nature is deeply integrated into education, she reflected on the impact this connection has on an individual's attitudes, fostering a sense of responsibility and a strong desire to protect the environment.

> This *[S7]* might be more important. I think that connection is the most important to make first with biology, because that is the connection that a lot of people are missing. ...If I think about biology and I think for example of the differences between how I was teaching it in Finland, there we are very connected to nature. ...

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

> If we understand the way nature is, in what state nature is, that also impacts us. Then I think we start protecting it more.
>
> (Teacher 13, Biology)

Another statement (S6) highlighting the competence of *promoting nature* emerged in Figure 5 as one of the most important competences in science education. Teachers associated with this factor array advocated science education that guides students in acknowledging the impact of their own behavior. Moreover, they supported the call to action inherent in this statement, emphasizing that students should not only recognize their impact on others and future generations but also act accordingly. Within this perspective, Teacher 16 emphasized the significance of students recognizing themselves as consumers, with the ability to influence the fair treatment of workers behind the products they choose to purchase.

> I tell this to the kids all the time, you go to a supermarket, you are a consumer. If you buy something, or if you do not buy it, that makes a difference. So, if you choose to buy something then you are saying that you are happy with that product. And if you are not happy, you should not buy it, you have the power. ...I make sure they know that they can make a difference. If everybody realizes they can make a difference, then there is hope.
>
> (Teacher 16, Biology)

The statements ranked lowest in this factor array are shown in Figure 6. According to this figure, the least importance was attributed in this factor array to *political agency* (S28, S29, S30), *collective action* (S32), *adaptability* (S23), and *supporting fairness* (S5). These statements are related to three *GreenComp* areas: "acting for sustainability," "envisioning sustainable futures," and "embracing complexity in sustainability," which have the color codes of green, yellow, and orange, respectively, in the figure.

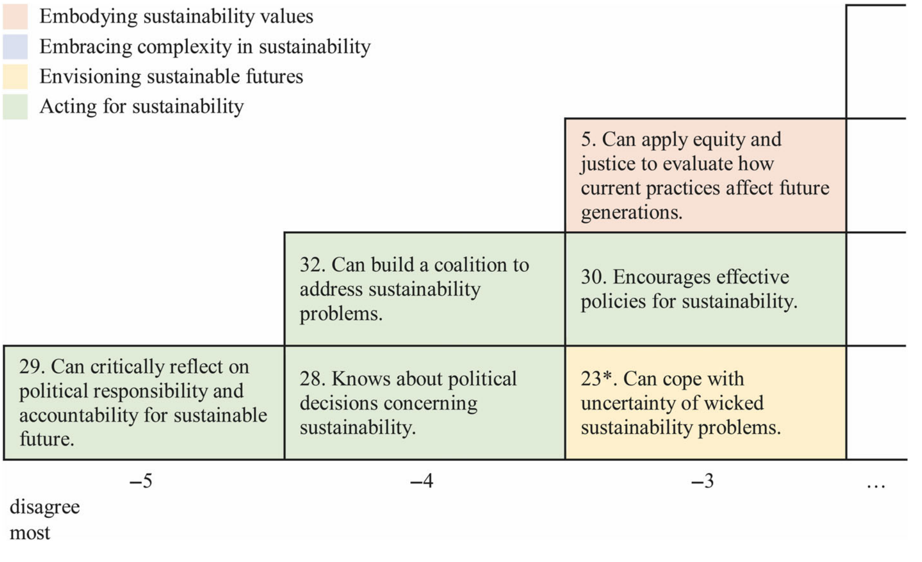

FIGURE 6 Lowest-ranked statements by Factor 2, where distinguishing statements are shown by an asterisk.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Facilitating the acquisition of critical reflection about political responsibility and accountability for a sustainable future was perceived as the least important competence in science education. While Teacher 11 acknowledged the importance of *political agency* as a general competence for students to acquire, she did not view it as relevant to address in her chemistry lessons. Instead, Teacher 11 suggested that this competence is addressed in history instruction, which provides a better context for exploring the effects of various political perspectives on sustainability.

> I think it is important for them to know that politics has an effect on the decisions that are being made, but I can see that is more taking place in history. They go further with showing what if you have a left party, or party more on the right side, and what that means for sustainability. Sustainability of course is not only about nature, I also realize that, but I think in chemistry, because as chemistry has such an impact on the environment, you focus more on that, I think.
>
> (Teacher 11, Chemistry)

Similar to Teacher 11, Teacher 14 acknowledged the importance of critically reflecting on political responsibility and accountability for secondary school students but did not find it relevant for her biology lessons. Teacher 14 noted that most of her students are not yet eligible to vote. Therefore, she considered it too early to implement competences related to politics in her lessons, given the age of her students.

> This has a lot to do with the political system in the Netherlands, and I feel like they do not have that much background here at school yet. I feel it is important, but for the biology lessons, it is less important. …You are talking about kids who of course need to start working toward the idea that they have a vote, politically speaking. But that is when they are 18. And I mostly teach lower grade students.
>
> (Teacher 14, Biology)

3.3 | Factor 3: Science education to promote collective action

This factor was the least dominant, with three physics teachers loading significantly, and it explained 8% of the dataset variance. Teachers who loaded on this factor worked at either a Dutch or bilingual secondary school. Analysis of the highest-ranked statements, shown in Figure 7, revealed that *exploratory thinking* (S26), *collective action* (S31, S33), *valuing sustainability* (S1), *adaptability* (S24), and *individual initiative* (S35) emerged as the most important competences in this factor array's prototype Q-sort. All the statements shown in Figure 7 have an asterisk, meaning that their ranking significantly distinguished the views captured in this factor array from those in the other two factor arrays.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

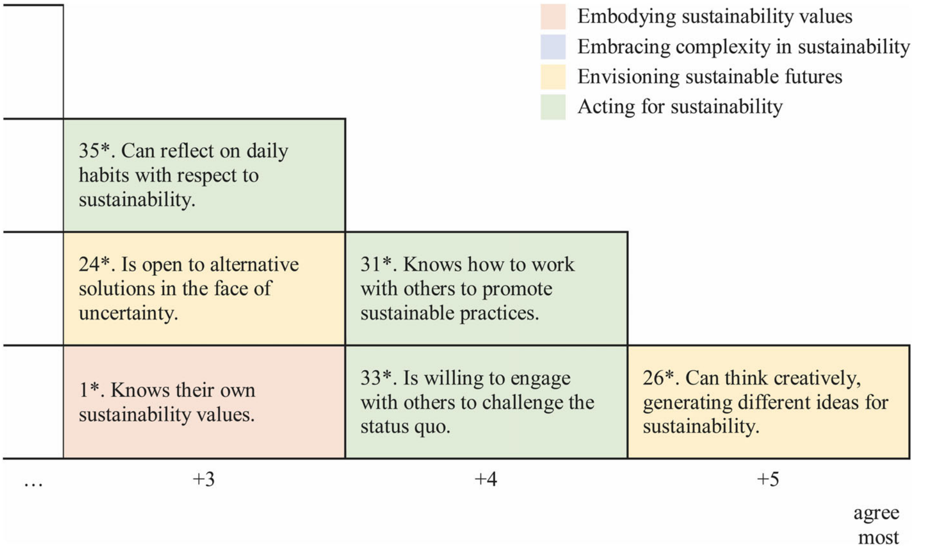

FIGURE 7 Highest-ranked statements by Factor 3, where distinguishing statements are shown by an asterisk.

The most important statement according to this factor array was about *exploratory thinking*. Thinking creatively and generating different ideas for sustainability (S26) was perceived as the most crucial competence in ESD, emphasizing the significance of innovative thinking. According to Teacher 3, fostering creative thinking is essential for tackling complex, multifaceted sustainability issues. Promoting *exploratory thinking* might be the only way to tackle these issues because it enables students to explore and generate diverse solutions, which is vital in the context of sustainability.

> Since the whole sustainability thing is a wicked problem, sometimes being creative is the only way out. Exploring options that might not have been explored or might have been dismissed in the view of some evidence…
>
> (Teacher 3, Physics)

The presence of three statements (S31, S33, S35) from the *GreenComp* competence area "acting for sustainability" in Figure 7 indicated a strong emphasis on this area compared to the other areas. This dominance suggests that the ability to take actions toward sustainability was considered the most crucial set of competences within this factor array. According to Teacher 2, willingness to engage with others to challenge the status quo (S33) is an important competence in science education, because it allows him to assess whether his students are experiencing autonomy. He emphasized that encouraging students to question and challenge existing norms fosters a sense of autonomy.

> It is a nice question to check whether they experience autonomy, because if they are not willing to engage with others, that is one thing, or if they are afraid to ask for help. But if they are afraid to challenge the status quo, then there is something repressive in their system.
>
> (Teacher 2, Physics)

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Teacher 3 highlighted the value of teaching students how to work with others to promote sustainable practices (S31), emphasizing that this competence is integral to the school's overall educational philosophy. At his school, collaboration among students is not only encouraged, but mandated as a key competence across the curriculum.

> This is at the core of what this school does. A core competence within the first 3 years is collaboration. Yesterday we had a session on some new rubrics for these competences, among which collaboration is one of them. We were asked to take those rubrics and embed them into our teaching.
>
> (Teacher 3, Physics)

Even though competences such as taking the initiative in a group project or working collaboratively with others are highly valued, Teacher 2 identified a significant challenge in addressing these competences: the role of parents. According to him, parents are crucial stakeholders in transforming secondary school education toward sustainability. However, they often prioritize measurable academic results, making it difficult for teachers to emphasize competences that are not easily quantified.

> Parents, however, they proved to be the biggest obstacle ...I think they want to see how their child is developing, and they do not know any better than with grades. ... They can see by numbers that there is growth, but the actual growth in their human being, in their development, they do not see.
>
> (Teacher 2, Physics)

When it comes to the lowest-ranked statements, shown in Figure 8, in this factor array the least importance was attributed to *supporting fairness* (S4, S5, S6), *political agency* (S28, S30), and *system thinking* (S12). All three statements covering *supporting fairness* were ranked among

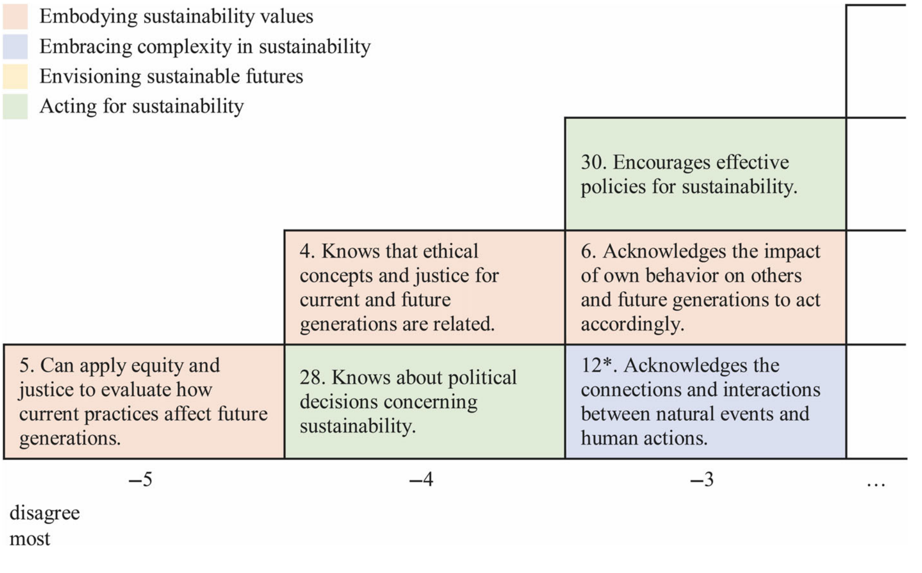

FIGURE 8 Lowest-ranked statements by Factor 3, where distinguishing statements are shown by an asterisk.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

the least important competences in Figure 8, meaning that *supporting fairness* was not considered as important as *exploratory thinking* or *collective action* in this factor array.

Teacher 3, who ranked Statement 5 as the least important competence, felt that *supporting fairness* should be handled by colleagues in the other subjects who are better equipped to discuss the concepts of equity and justice. His focus was on evidence-based science teaching, which he believed was more within his expertise and teaching style.

> I tend to be too black-and-white for that sometimes, too scientific. Which means it is not my place as a person, or as a teacher to engage with these competences. But I know colleagues who can do this. ...colleagues who teach philosophy. I tend to focus more on the scientific side, on the evidence-based side of what can we do.
>
> (Teacher 3, Physics)

Additionally, Teacher 3 expressed that he finds it difficult to set clear, achievable learning goals related to *supporting fairness*. He stressed the importance of knowing the end goal to ensure high-quality education, but acknowledged the uncertainty required when dealing with competences such as *supporting fairness*.

> ...only if I know the end goal of what I want to achieve with the students I can reason about how to get there. ...Some of these competences I cannot put into a learning goal. I am not sure what the end goal will be.
>
> (Teacher 3, Physics)

3.4 | Characteristic statements for factor arrays and their overlap

Our study identified three factor arrays based on 16 science teachers' views on *GreenComp* competences. While each array offered a unique viewpoint, there was consensus among them regarding the importance associated with certain statements. Conversely, specific statements were exclusively endorsed in only one of the three factor arrays, representing areas of disagreement. Both the consensus and disagreement between and among the factor arrays are illustrated in a Venn diagram, presented in Figure 9, where each factor array is represented by circles. This diagram was manually constructed after establishing criteria for categorizing the statements. We considered only those ranked at extremes (+3, +4, +5 or −3, −4, −5) in at least one factor array, excluding all-negative or mixed negative and neutral rankings. Statements with positive rankings below +3 in two factor arrays and negative or neutral in the third were excluded due to lack of high agreement.

In this figure, statements ranked as positive in every factor array are shown at the intersection of all circles, representing consensus. For example, *critical thinking* emerged as important across all factor arrays, due to statements (S14, S15) related to this competence appearing at the intersection where all three circles overlap. Statements ranked as positive in one factor array, but as negative or neutral in the others, are placed within its circle, as they are characteristic of that factor array. For example, what distinguished Factor 1 was its emphasis on *problem framing* (S16). While Factor 2 highlighted the importance of *supporting fairness* (S6) and *promoting nature* (S7), Factor 3 stood out for its emphasis on *collective action* (S31, S33). It is

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

noteworthy that Figure 9 illustrates the significance associated with certain statements. However, all three statements covering the competence of *political agency* were ranked as one of the least important statements in each factor array, indicating a distinct type of consensus—consensus about its insignificance across the factor arrays.

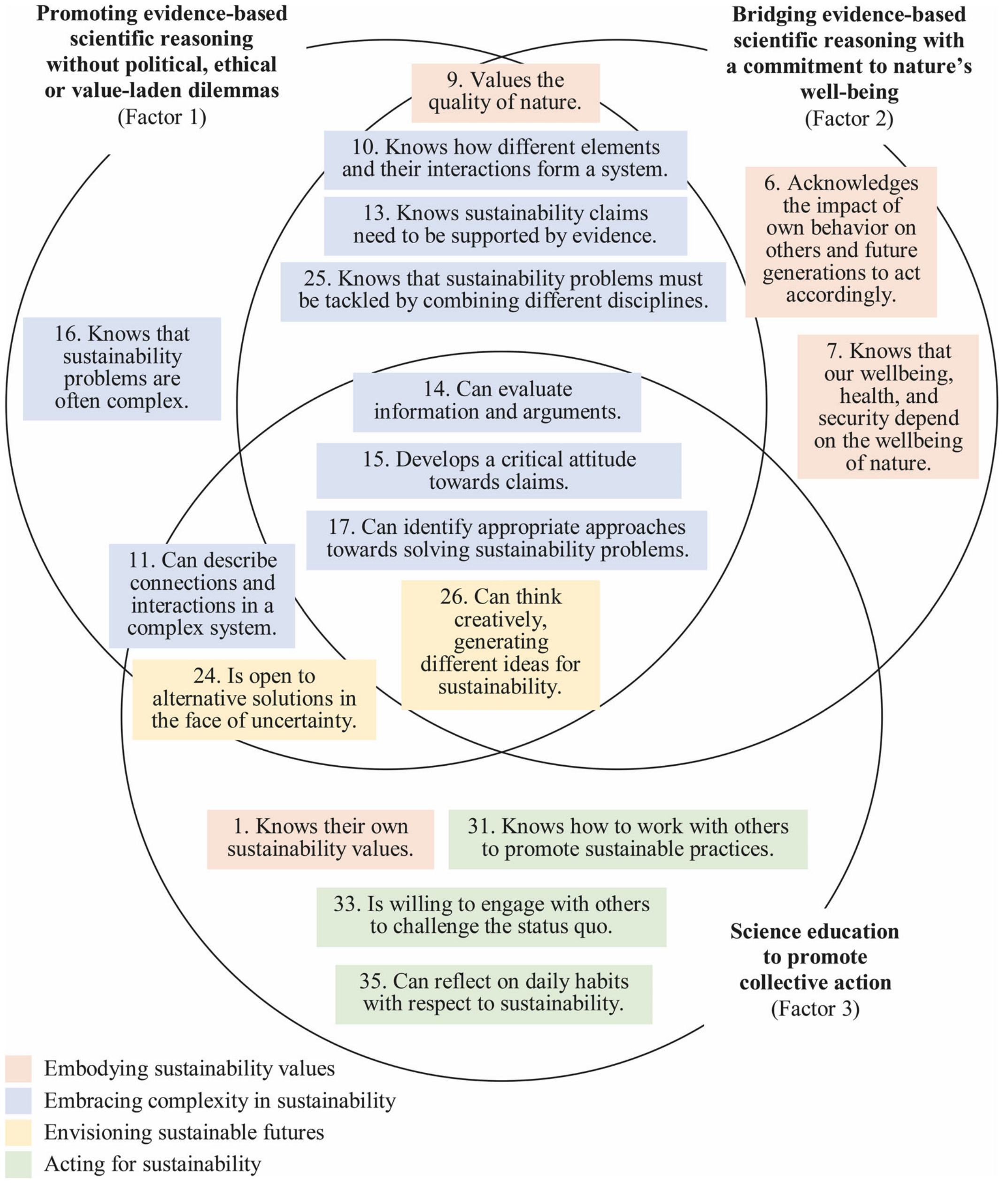

FIGURE 9 Consensus and disagreements between and among the factor arrays, where overlapping regions indicate agreed-upon statements and non-overlapping regions indicate characteristic statements for each factor array.

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

4 | DISCUSSION AND IMPLICATIONS

In this exploratory study, we aimed at identifying science teachers' views on student competences in ESD. The ambition of this study was to explore what views science teachers hold, and their reasoning behind attributing significance to certain competences while dismissing others. This was achieved by using Q methodology, where the statements we used was grounded in the *GreenComp* competence framework developed by the European Commission (Bianchi et al., 2022). The fact that Q methodology required participating teachers to rank the statements relative to one another in terms of teachers' level of agreement regarding the importance of the competence described in the statements allowed us to capture the relative importance of competences in ESD.

Our study revealed that the views of our participating science teachers could be grouped into three factor arrays. In the most dominant factor array, associated with a factor upon which nine teachers loaded significantly, promoting evidence-based instruction without addressing the political, ethical or value-laden dilemmas inherent in sustainability issues is advocated. In the second most dominant factor array, with four associated teachers, bridging evidence-based instruction with a commitment to nature's well-being is advocated. In the factor array associated with the smallest group, three physics teachers, the idea that science education should promote collective action for ESD is advocated.

Our findings indicated that *critical thinking* and *system thinking* are regarded as important in all three factor arrays, though to varying degrees. Common among teachers who loaded on Factor 1 is the view that science is value-free, empirical and objective. This aligns with the findings in previous literature that compared with other content-area teachers, science teachers considered cultural issues the least frequently (Uitto & Saloranta, 2017). Moreover, this is consistent with the Vision I perspective on the purposes of science education (Roberts & Bybee, 2014), and the tendency of science teachers to present science as a rigid body of theories and rules (Borg et al., 2012; Bossér et al., 2015; Levinson & Turner, 2002; van Driel et al., 2001). On the other hand, the competence of *political agency* is one of the least important competences in all arrays. All of our participants agreed on excluding political dimensions of sustainability issues from their lessons. This consensus on the insignificance of *political agency* in science education is unique, as it is the only instance where all three statements related to a single competence (S28, S29, S30) were ranked as negative, mostly at the extreme, in each factor array. No other competence was revealed in our study to show such agreement across its three statements. Some teachers who loaded on Factor 1 even argued that science is inherently apolitical. While the literature on science teachers' attitude toward integrating political aspects of sustainability issues is limited, our study makes a significant contribution by not only confirming their reluctance to do so (Dunlop et al., 2024), but also revealing a key reason: their perception of science as a discipline.

Some may argue that not all competences outlined in policy documents, such as the *GreenComp* competence framework, need to be addressed in science lessons. Based on this viewpoint, as 12 out of 16 participating teachers also suggested, politics or ethics can be excluded from the science classroom and instead be tackled in social-science subjects such as history or philosophy. However, others, including ourselves, argue that such an approach undermines the role of science education in fostering comprehensive understanding and engagement with societal issues. For this reason, we find the stance taken by the most dominant group of teachers in our study concerning, because any approach to science teaching is inadequate if it does not address the concepts of ethics, justice, and values, and these concepts should not be taught as independent (Sjöström et al., 2017; Tuncay-Yüksel et al., 2023; Zeidler et al., 2005; Zeidler & Sadler, 2023). We consider the suggestion by most of our participating teachers that another subject is more suitable for addressing certain competences to be one of the most significant contributions of our study. However, further research is needed to determine if this exploratory finding reflects a broader attitude among science teachers. Additionally, developing a horizontal curriculum to clarify which competences are to be addressed in each subject and year group could help researchers assess the current state of affairs and enable schools to address any gaps.

Some teachers argued that acquiring scientific knowledge through developing *critical thinking* and *system thinking* will naturally lead to the development of values, which will prompt students to act accordingly. Competences regarding behavioral changes, values, or attitudes were seen as "side-effects," or as concurrent outcomes of teaching scientific content rather than primary goals. This finding supports previous research on teaching traditions in ESD, revealing that some teachers believe that the right knowledge will automatically lead to better values and actions (Sund & Gericke, 2021). Additionally, when considering various stakeholders in ESD, scientists' views on competences to be acquired by secondary school students under-represent the importance of norms and values (Günther et al., 2024). This leads us to believe that much importance is attributed to acquisition of scientific knowledge, although it is known that sustainability problems cannot be solved with knowledge only (Bianchi et al., 2022). As suggested in previous studies, including more meta-reflection in professional development and training programs can help science teachers to realize ESD (Jegstad et al., 2018; Stevenson et al., 2015). Moreover, how to express ESD should be clear for teacher educators to be clear for teachers, because content-area traditions are important factors that influence teachers' uptake of ESD (Stables & Scott, 2002; Uitto & Saloranta, 2017). The successful adaptation of reform-oriented instruction depends on teachers' own experiences as learners, which in this case shape their views on effective science teaching (Johnson, 2006). Therefore, our results show that science teachers' stand on certain ESD competences should be taken into consideration, considering that any attempt to implement educational change without targeting subject-matter teachers explicitly may fail (Borg et al., 2012, 2013). We believe our findings have the potential to enhance the professional development and training of both in-service and pre-service teachers. In this context, science teachers' views and which vision of the purposes of science education they hold should be taken into consideration for meaningful professional development and teacher training. Kim's (2024) study showed that although science teachers initially considered justice-oriented science teaching to be "barely relevant," their understanding evolved through reflective sensemaking, allowing them to explore the meaning of culture and politics within their own context of science teaching. Therefore, science teachers' approach to teaching can change through sensemaking. In this regard, another implication of our results could be the value of engaging science teachers in a discussion regarding the three visions for science education (Roberts, 2007; Sjöström et al., 2017). Teachers who hold similar views as most of our participants would benefit from being engaged in a such a discussion and their approach might change as a result.

Some teachers who loaded on Factor 1 would be self-critical if they were to implement competences related to values, fearing they would be imposing their own values on students. They felt that implementing competences related to *supporting fairness* or *promoting nature* would involve preaching their own values to students. This concern, highlighted by Jickling and Wals (2008), reflects a broader worry about the normative aspect of ESD. Policy experts in ESD have similarly cautioned against this risk with respect to implementing ESD competences in

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

secondary schools (Günther et al., 2024). In contrast, however, teachers who loaded on Factor 2 felt responsible for *supporting fairness* and *promoting nature*, while those who loaded on Factor 3 emphasized promoting sustainable practices in the form of *collective action*. These differences suggest that the importance teachers place on certain competences may stem from how they perceive their roles as teachers. While it is already known that science teachers often do not consider addressing societal issues to be part of their role (Lee & Yang, 2019), our research advances the literature by identifying a potential reason for this reluctance. Some teachers may avoid these topics out of concern that they would be imposing their own values on students. Further research is needed to explore instructional strategies that enable science teachers to address societal issues without feeling as though they are preaching or imposing their values.

When asked why *political agency* and *supporting fairness* were ranked as the least important competences, Teacher 5 reasoned that he does not consider himself as the right person to introduce politics-related issues, while Teacher 10 argued that she does not feel confident in navigating discourse because it involves emotions. Teachers' positioning as dismissing the political or ethical dilemmas in science lessons could be explained by drawing on previous research that science teachers are not well-equipped to navigate debates (Chen & Xiao, 2021). They feel ill-prepared to address the interdisciplinary aspect of sustainability issues (Boeve-de Pauw et al., 2022). As Teacher 6 suggested, collaboration between science teachers and social-science content teachers might enable science teachers to incorporate the interdisciplinary nature of sustainability issues into their teaching. Therefore, the view of science as value-free and empirical is not the only reason why science teachers dismiss certain competences. A lack of knowledge of politics-related issues and a lack of knowledge of instructional strategies such as navigating discourse were revealed in our results as reasons for science teachers to rank politics- or ethics-related competences low. While traditional science teaching is based on the division of disciplines, societal challenges require educators to adopt interdisciplinarity in their lessons (Ming et al., 2023; van den Beemt et al., 2020). In this regard, we acknowledge the need for communication and collaboration among science teachers, and between science and social science content teachers, as suggested in the literature (Chen & Xiao, 2021). It is known that teachers who teach social-science content use class discussions more often than science teachers for ESD (Borg et al., 2012) and focus on action competence and political responsibility (Sund & Gericke, 2020). As Johnson (2006) suggested, collaborative relationships within schools are crucial to achieve the transformation needed for reform-based instruction, not only in the case of implementing ESD successfully in science lessons, but in any educational reforms. Secondary school teachers are trained within specific disciplines during their teacher education programs, making them more comfortable with discipline-bound teaching methods (Stables & Scott, 2002). Given this, approaching secondary school teachers from within the confidence of their discipline and supporting them to collaborate with other disciplines can empower them as successful facilitators of ESD (Stables & Scott, 2002).

Another remarkable result revealed in our study was the perceived role of parents and assessment when it comes to implementing ESD competences. Teachers who loaded on Factor 1 and Factor 2 referred to internal reasons such as their perception of science as a discipline or lack of confidence to justify their low rankings. Only those who loaded on Factor 3 cited external reasons: parents' role and assessment. For instance, Teacher 2 was not hesitant to identify parents as obstacles to implementing the ESD competences he found important. He noted that parents often focused on quantitative evaluation of their children's progress, which contrasts with the qualitative assessment required for ESD competences. Fullan (2015) discussed the dilemma schools face regarding parental involvement in educational change, highlighting

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

the importance of communication between schools and parents. We consider this as one of the important contributions of our study, which suggests that implementing ESD competences necessitates a shift in assessment practices and communication with parents. Without parental understanding and support, this shift may encounter resistance and prove ineffective. Teachers who perceive parents as barriers to change may opt for traditional teaching methods to avoid confrontation, potentially hindering progress toward ESD. Thus, involving parents in the educational change process could enhance the success of ESD implementation. Additionally, as a reason to dismiss *supporting fairness*, Teacher 3 argued that it is difficult for a teacher to know the end result of incorporating such a competence. He explained that competences such as *supporting fairness* cannot be put into a learning goal to be assessed. This implies that teachers' current knowledge about learning goals and how to assess them hinders their uptake of certain ESD competences. In the case of sustainability issues and developing students' ESD competences, the end goal of a lesson might be open-ended. We recognize a need for science teachers to be equipped with assessment strategies that would allow them to evaluate the development of competences such as *supporting fairness*. Therefore, further research is needed to test and design effective assessment tools for science teachers to address certain ESD competences in their lessons. This would empower science teachers to transform their approach to teaching from pre-set, already determined end goals toward open-ended ones. Implementing these competences in ESD in secondary school science education is not about reaching pre-determined goals, it is about involving the students in the process of addressing the sustainability issues.

Finally, we are hesitant to explore potential relationships between the views captured in three factor arrays and our participants' contextual characteristics due to the sample size. However, we believe that insights can be gained from our results for further research. We suggest that factors such as a teacher's discipline—whether physics, chemistry, or biology—could play a role in their views, because majority of the teachers who loaded on Factor 1 in our study were chemistry teachers, while those loading on Factor 2 predominantly consisted of biology teachers, and those loading on Factor 3 consisted only of physics teachers. A larger study could employ Q methodology similar to ours, allowing for the Q-sorting activity to be conducted online, thus enabling researchers to reach a broader sample across each discipline. Following by-person factor analysis, only teachers with the highest factor loadings could be invited for semi-structured interviews. Therefore, we recognize the value of Q methodology in educational research, as well as its potential use in both small- and large-scale studies.

5 | CONCLUSION

Top-down approaches such as the *GreenComp* competence framework developed by the European Commission (Bianchi et al., 2022) or the OECD's (2023) emphasis on environmental awareness have expectations of science education, but fail to consider teachers' personal epistemology regarding science and scientific knowledge, their teaching orientations and habits or practices. There is no "one size fits all" solution that will effectively facilitate the acquisition of ESD competences in secondary schools. Teachers differ in terms of their views and their reasoning about dismissing or embracing certain competences in their teaching. This places a big responsibility on policymakers, teacher educators, and professional development designers. If we aim at preparing scientifically literate students who act sustainably, we first need to empower science teachers with the knowledge, skills, and attitudes needed for implementing ESD. Science-teacher educators should place greater emphasis on epistemological beliefs,

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

ethics, values, and politics within their science education programs. While some teachers might need support to reflect on the way they perceive science and their roles as teachers, others might benefit from collaborating with social-science content teachers to gain expertise in navigating discourse and discussing ethics and politics in science classrooms. We believe that a rethink is needed for policymakers because if the policy documents do not target content teachers explicitly, one teacher might think that it is the other content teacher's role to integrate certain competences. Challenges arise when addressing reform-oriented goals in education, including, but not limited to, the implementation of ESD in science education. These challenges can be tackled by taking teachers' views into account while supporting them as change agents.

6 | LIMITATIONS

The conclusions are limited to the particular situation examined in this study for several reasons. This study reports only 16 science teachers' views on competences in ESD, and Q methodology findings cannot be generalized to entire populations of people (Watts & Stenner, 2012). The explained variance in our study was 48%. This means that 52% of the variance was not captured in our participants' views. Therefore, an average science teacher's views may not be represented in our results. Moreover, the teachers participated in our study voluntarily, motivated to share their views on ESD competences. The participants may thus have been more interested in sustainability education than the average science teacher. Even though our results should be considered in light of the exploratory nature of this study, insights were still gained to better empower science teachers as facilitators of ESD.

ACKNOWLEDGMENTS

This research was funded by the Dutch Research Council (NWO), grant number 40.5.22395.002. The study adhered to the ethical guidelines provided by the Eindhoven University of Technology. Ethical approval code was ERB2023AP3a. The authors express their gratitude to the teachers who participated in this study.

ORCID

Tuba Stouthart https://orcid.org/0000-0003-0930-306X
Dury Bayram https://orcid.org/0000-0001-9502-1928
Jan van der Veen https://orcid.org/0000-0001-5196-6591

REFERENCES

Annan-Diab, F., & Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the sustainable development goals. *International Journal of Management Education*, *15*(2), 73–83. https://doi.org/10.1016/j.ijme.2017.03.006

Banasick, S. (2019). KADE: A desktop application for Q methodology. *Journal of Open Source Software*, *4*(36), 1–4. https://doi.org/10.21105/joss.01360

Bianchi, G. (2020). Sustainability competences. *A Systematic Literature Review*, 73. https://doi.org/10.2760/200956

Bianchi, G., Pisiotis, U., & Cabrera, M. (2022). *GreenComp□The European sustainability competence framework*. Publications Office of the European Union. https://doi.org/10.2760/13286

Boeve-de Pauw, J., Olsson, D., Berglund, T., & Gericke, N. (2022). Teachers' ESD self-efficacy and practices: A longitudinal study on the impact of teacher professional development. *Environmental Education Research*, *28*(6), 867–885. https://doi.org/10.1080/13504622.2022.2042206

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Borg, C., Gericke, N., Höglund, H. O., & Bergman, E. (2012). The barriers encountered by teachers implementing education for sustainable development: Discipline bound differences and teaching traditions. *Research in Science and Technological Education*, *30*(2), 185–207. https://doi.org/10.1080/02635143.2012.699891

Borg, C., Gericke, N., Höglund, H.-O., & Bergman, E. (2013). Subject- and experience-bound differences in teachers' conceptual understanding of sustainable development. *Environmental Education Research*, *20*(4), 526–551. https://doi.org/10.1080/13504622.2013.833584

Bossér, U., Lundin, M., Lindahl, M., & Linder, C. (2015). Challenges faced by teachers implementing socio-scientific issues as core elements in their classroom practices. *European Journal of Science and Mathematics Education*, *3*(2), 159–176. https://doi.org/10.30935/scimath/9429

Brown, S. R. (1980). *Political subjectivity: Applications of Q methodology in political science*. Yale University Press.

Brown, S. R. (1996). Q methodology and qualitative research. *Qualitative Health Research*, *6*(4), 561–567. https://doi.org/10.1177/104973239600600408

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P., & Zint, M. (2021). Key competencies in sustainability in higher education□Toward an agreed-upon reference framework. *Sustainability Science*, *16*, 13–29. https://doi.org/10.1007/s11625-020-00838-2

Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability*, *7*(3), 2768–2786. https://doi.org/10.3390/su7032768

Charro, E. (2020). A curricular Delphi study to improve the science education of secondary school students in Spain. *Journal of Research in Science Teaching*, *58*(2), 282–304. https://doi.org/10.1002/tea.21655

Chen, L., & Xiao, S. (2021). Perceptions, challenges and coping strategies of science teachers in teaching socioscientific issues: A systematic review. *Educational Research Review*, *32*, 100377. https://doi.org/10.1016/j.edurev.2020.100377

Day, S. P., & Bryce, T. G. K. (2011). Does the discussion of socio-scientific issues require a paradigm shift in science teachers' thinking? *International Journal of Science Education*, *33*(12), 1675–1702. https://doi.org/10.1080/09500693.2010.519804

Dunlop, L., Atkinson, L., Malmberg, C., Turkenburg-Van Diepen, M., Urbas, A., & Se, A. U. (2024). Treading carefully: The environment and political participation in science education. *Cultural Studies of Science Education*, *19*, 317–339. https://doi.org/10.1007/s11422-024-10215-5

ESERA. (2024). Embracing Transitions in Science Education. https://www.esera.org/conference-2025

Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education*, *93*(6), 1076–1095. https://doi.org/10.1002/sce.20349

Fischer, D., King, J., Rieckmann, M., Barth, M., Büssing, A., Hemmer, I., & Lindau-Bank, D. (2022). Teacher education for sustainable development: A review of an emerging research field. *Journal of Teacher Education*, *73*(5), 509–524. https://doi.org/10.1177/00224871221105784

Forsler, A., Nilsson, P., & Walan, S. (2024). What and why in teaching about sustainability□Swedish science teachers' emphasis on content choice when teaching sustainable development. *Nordic Studies in Science Education*, *20*(1), 4–21. https://doi.org/10.5617/nordina.10159

Fullan, M. (2015). *The new meaning of educational change* (5th ed.). Routledge.

Gray, D. S., & Bryce, T. (2006). Socio-scientific issues in science education: Implications for the professional development of teachers. *Cambridge Journal of Education*, *36*(2), 171–192. https://doi.org/10.1080/03057640600718489

Günther, J., Muster, S., Kaiser, K., & Rieckmann, M. (2024). A multi-stakeholder perspective on the development of key competencies for sustainability in education for sustainable development at school. *Environmental Education Research*, *30*, 1651–1667. https://doi.org/10.1080/13504622.2024.2349934

Guttman, L. (1954). Some necessary conditions for common-factor analysis. *Psychometrika*, *19*, 149–161. https://doi.org/10.1007/BF02289162

Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching*, *33*(9), 971–993. https://doi.org/10.1002/(SICI)1098-2736(199611)33:9<971::AID-TEA2>3.0.CO;2-S

Harskamp, M., Knippels, M. C. P. J., & van Joolingen, W. R. (2021). Secondary science teachers' views on environmental citizenship in The Netherlands. *Sustainability*, *13*(14), 7963. https://doi.org/10.3390/su13147963

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Hyland, T. (1994). *Competence, education and national vocational qualifications: Dissenting perspectives*. Cassell Education.

Jegstad, K. M., Sinnes, A. T., & Gjøtterud, S. M. (2018). Science teacher education for sustainable development: From intensions to realisation. *Nordic Studies in Science Education*, *14*(4), 350–367. https://doi.org/10.5617/nordina.3263

Jickling, B., & Wals, A. E. J. (2008). Globalization and environmental education: Looking beyond sustainable development. *Journal of Curriculum Studies*, *40*(1), 1–21. https://doi.org/10.1080/00220270701684667

Johnson, C. C. (2006). Effective professional development and change in practice: Barriers science teachers encounter and implications for reform. *School Science and Mathematics*, *106*(3), 150–161. https://doi.org/10.1111/j.1949-8594.2006.tb18172.x

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151. https://doi.org/10.1177/001316446002000116

Karaarslan, G., & Teksoz, G. (2016). Integrating sustainable development concept into science education program is not enough; we deed competent science teachers for education for sustainable development–Turkish experience. *International Journal of Environmental and Science Education*, *11*(15), 8403–8424. https://hdl.handle.net/11511/81999

Kaya, E., Erduran, S., & Okan, B. (2024). Nature of science and domain-specificity: Investigating the coverage of nature of science in physics, chemistry and biology curricula across grade levels. *International Journal of Science Education*, 1–31. https://doi.org/10.1080/09500693.2024.2348822

Kayumova, S., & Dou, R. (2022). Equity and justice in science education: Toward a pluriverse of multiple identities and onto-epistemologies. *Science Education*, *106*(5), 1097–1117. https://doi.org/10.1002/sce.21750

Kilinc, A., Demiral, U., & Kartal, T. (2017). Resistance to dialogic discourse in SSI teaching: The effects of an argumentation-based workshop, teaching practicum, and induction on a preservice science teacher. *Journal of Research in Science Teaching*, *54*(6), 764–789. https://doi.org/10.1002/tea.21385

Kim, W. J. (2024). "At first they felt barely relevant": Teacher reflective sensemaking of justice-oriented science teaching. *International Journal of Science Education*, *1–22*, 1–22. https://doi.org/10.1080/09500693.2024.2344128

Kinskey, M., & Zeidler, D. (2021). Elementary preservice teachers' challenges in designing and implementing socioscientific issues-based lessons. *Journal of Science Teacher Education*, *32*(3), 350–372. https://doi.org/10.1080/1046560X.2020.1826079

Laherto, A., Rasa, T., Miani, L., Levrini, O., & Erduran, S. (2023). Future-oriented science education building sustainability competences: An approach to the European GreenComp framework. In *Science curriculum for the anthropocene, volume 2* (pp. 83–105). Springer. https://doi.org/10.1007/978-3-031-37391-6_5

Lee, H., & Yang, J.-E. (2019). Science teachers taking their first steps toward teaching socioscientific issues through collaborative action research. *Research in Science Education*, *49*, 51–71. https://doi.org/10.1007/s11165-017-9614-6

Levinson, R., & Turner, S. (2002). *Valuable lessons: Engaging with the social context of science in schools. Recommendations and summary of research findings*. The Wellcome Trust. https://wellcome.org/sites/default/files/wtd003446_0.pdf

Lundberg, A., de Leeuw, R., & Aliani, R. (2020). Using Q methodology: Sorting out subjectivity in educational research. *Educational Research Review*, *31*, 100361. https://doi.org/10.1016/j.edurev.2020.100361

Mathie, R. G., & Wals, A. E. J. (2022). *Whole school approaches to sustainability: Exemplary practices from around the world*. Wageningen University. https://doi.org/10.18174/572267

Ming, X., MacLeod, M., & van der Veen, J. (2023). Construction and enactment of interdisciplinarity: A grounded theory case study in liberal arts and sciences education. *Learning, Culture and Social Interaction*, *40*, 100716. https://doi.org/10.1016/J.LCSI.2023.100716

Mulà, I., & Tilbury, D. (2023). Teacher education for sustainability: Current practice and outstanding challenges. *Avances de Investigación En Educación Matemática*, *23*, 5–18. https://doi.org/10.35763/aiem23.5414

NARST. (2024). Science education for the rest of us. https://narst.org/conferences/2024-annual-conference

Nordqvist, O., & Jidesjö, A. (2023). Upper secondary school science teachers' values in Sweden: What decides what is taught? *Science and Education*, *33*, 1595–1613. https://doi.org/10.1007/s11191-023-00446-3

OECD. (2019). Future of education and skills 2030. Learning compass 2030□A series of concept notes. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/learning-compass-2030/OECD_Learning_Compass_2030_Concept_Note_Series.pdf

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

OECD. (2023). PISA 2025 science framework draft. https://pisa-framework.oecd.org/science-2025/

Redman, A., & Wiek, A. (2021). Competencies for advancing transformations towards sustainability. *Frontiers in Education*, *6*, 1–11. https://doi.org/10.3389/feduc.2021.785163

Rieckmann, M. (2012). Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? *Futures*, *44*(2), 127–135. https://doi.org/10.1016/j.futures.2011.09.005

Rieckmann, M. (2017). Learning to transform the world: Key competencies in education for sustainable development. In A. Leicht, J. Heiss, & W. J. Byun (Eds.), *Issues and trends in education for sustainable development* (pp. 39–59). UNESCO.

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell, K. Appleton, & D. Hanuscin (Eds.), *Handbook of research on science education* (pp. 729–780). Routledge.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. 2, pp. 545–558). Routledge. https://doi.org/10.4324/9780203097267

Ryder, J., & Banner, I. (2013). School teachers' experiences of science curriculum reform. *International Journal of Science Education*, *35*(3), 490–514. https://doi.org/10.1080/09500693.2012.665195

Sadler, T. D., Amirshokoohi, A., Kazempour, M., & Allspaw, K. M. (2006). Socioscience and ethics in science classrooms: Teacher perspectives and strategies. *Journal of Research in Science Teaching*, *43*(4), 353–376. https://doi.org/10.1002/tea.20142

Schipper, E. L. F., Dubash, N. K., & Mulugetta, Y. (2021). Climate change research and the search for solutions: Rethinking interdisciplinarity. *Climatic Change*, *168*, 18. https://doi.org/10.1007/s10584-021-03237-3

Sipos, Y., Battisti, B., & Grimm, K. (2008). Achieving transformative sustainability learning: Engaging head, hands and heart. *International Journal of Sustainability in Higher Education*, *9*(1), 68–86. https://doi.org/10.1108/14676370810842193

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning. *Studies in Science Education*, *58*(2), 282–304. https://doi.org/10.1080/03057267.2017.1384649

SLO. (2024). Conceptkerndoelen: burgerschap en digitale geletterdheid [Core objectives: Citizenship and digital literacy]. https://slo-kerndoelen.files.svdcdn.com/production/uploads/assets/updates/DEF_kerndoelenboekje_BU_DG.pdf?dm=1709640714

Spillane, J. P. (1999). External reform initiatives and teachers' efforts to reconstruct their practice: The mediating role of teachers' zones of enactment. *Journal of Curriculum Studies*, *31*(2), 143–175. https://doi.org/10.1080/002202799183205

Stables, A., & Scott, W. (2002). The quest for holism in education for sustainable development. *Environmental Education Research*, *8*(1), 53–60. https://doi.org/10.1080/13504620120109655

Stevenson, R. B., Ferreira, J.-A., Evans, N., & Davis, J. (2015). Beyond science education: Embedding sustainability in teacher education systems. In S. K. Stratton, R. Hagevik, A. Feldman, & M. Bloom (Eds.), *Educating science teachers for sustainability* (pp. 381–398). Springer. http://www.springer.com/series/11803

Sund, P., & Gericke, N. (2020). Teaching contributions from secondary school subject areas to education for sustainable development□A comparative study of science, social science and language teachers. *Environmental Education Research*, *26*(6), 772–794. https://doi.org/10.1080/13504622.2020.1754341

Sund, P., & Gericke, N. (2021). More than two decades of research on selective traditions in environmental and sustainability education□seven functions of the concept. *Sustainability*, *13*(6524), 1–14. https://doi.org/10.3390/su13126524

Tidemand, S., & Nielsen, J. A. (2016). The role of socioscientific issues in biology teaching: From the perspective of teachers. *International Journal of Science Education*, *39*(1), 44–61. https://doi.org/10.1080/09500693.2016.1264644

Tuncay-Yüksel, B., Yılmaz-Tüzün, Ö., & Zeidler, D. L. (2023). Epistemological beliefs and values as predictors of preservice science teachers' environmental moral reasoning. *Journal of Research in Science Teaching*, *60*(9), 2111–2144. https://doi.org/10.1002/tea.21889

Uitto, A., & Saloranta, S. (2017). Subject teachers as educators for sustainability: A survey study. *Education Sciences*, *7*(1), 8. https://doi.org/10.3390/educsci7010008

UNESCO. (2020). Education for sustainable development: A roadmap. https://unesdoc.unesco.org/ark:/48223/pf0000374802?posInSet=2&queryId=3779a679-30bd-4f04-b0fa-20904abec4c5

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

UNESCO. (2023). Empowering learners and teachers for climate action. https://unesdoc.unesco.org/ark:/48223/pf0000387951

van den Beemt, A., Macleod, M., van der Veen, J., van de Ven, A., van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education*, *109*(3), 508–555. https://doi.org/10.1002/jee.20347

van der Leij, T., Goedhart, M., Avraamidou, L., & Wals, A. (2023a). Designing a module for supporting secondary biology students' morality through socioscientific issues in the human-nature context. *Journal of Biological Education*, *58*, 1186–1203. https://doi.org/10.1080/00219266.2023.2174160

van der Leij, T., Goedhart, M., Avraamidou, L., & Wals, A. (2023b). High school biology students' use of values in their moral argumentation and decision-making. *Journal of Moral Education*, *53*, 388–411. https://doi.org/10.1080/03057240.2023.2185595

van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*(2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

Vare, P., Rieckmann, M., & Lausselet, N. (2022). Introduction. In P. Vare, N. Lausselet, & M. Rieckmann (Eds.), *Competences in education for sustainable development* (pp. 3–10). Springer. https://link.springer.com/bookseries/15486

Wals, A. E. J. (2014). Sustainability in higher education in the context of the UN DESD: A review of learning and institutionalization processes. *Journal of Cleaner Production*, *62*, 8–15. https://doi.org/10.1016/j.jclepro.2013.06.007

Wals, A. E. J., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science*, *344*(6184), 583–584. https://doi.org/10.1126/science.1250515

Watts, S., & Stenner, P. (2012). *Doing Q methodological research*. Sage Publications.

Wiek, A., Bernstein, M. J., Foley, R. W., Cohen, M., Forrest, N., Kuzdas, C., Kay, B., & Withycombe Keeler, L. (2016). Operationalising competencies in higher education for sustainable development. In M. Barth, G. Michelsen, M. Rieckmann, & I. Thomas (Eds.), *Handbook of higher education for sustainable development* (pp. 241–260). Routledge. https://www.researchgate.net/publication/283295405

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*, 203–218. https://doi.org/10.1007/s11625-011-0132-6

Witz, K., & Lee, H. (2009). Science as an ideal: Teachers' orientations to science and science education reform. *Journal of Curriculum Studies*, *41*(3), 409–431. https://doi.org/10.1080/00220270802165640

Zeidler, D. L., Applebaum, S. M., & Sadler, T. D. (2011). Enacting a socioscientific issues classroom: Transformative transformations. In T. D. Sadler (Ed.), *Socio-scientific issues in the classroom* (pp. 277–305). Springer. https://doi.org/10.1007/978-94-007-1159-4_16

Zeidler, D. L., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research*, *1*(11), 1–9. https://doi.org/10.1186/s43031-019-0008-7

Zeidler, D. L., & Sadler, T. D. (2011). An inclusive view of scientific literacy: Core issues and future directions. In C. Linder, L. Östman, D. A. Roberts, P.-O. Wickman, G. Ericksen, & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (pp. 12–17). Routledge. https://doi.org/10.4324/9780203843284

Zeidler, D. L., & Sadler, T. D. (2023). Exploring and expanding the Frontiers of socioscientific issues. In N. G. Lederman, D. L. Zeidler, & J. S. Lederman (Eds.), *Handbook of research on science education* (Vol. 3, pp. 899–929). Routledge. https://doi.org/10.4324/9780367855758-33

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, *89*(3), 357–377. https://doi.org/10.1002/sce.20048

How to cite this article: Stouthart, T., Bayram, D., & van der Veen, J. (2025). Science teachers' views on student competences in education for sustainable development. *Journal of Research in Science Teaching*, 1–37. https://doi.org/10.1002/tea.22021

10982736, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.22021, Wiley Online Library on [27/01/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License