TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Secondary school teachers' experiences in extending education for sustainable development beyond their classrooms

Citation for published version (APA):
Stouthart, T., Bayram, D. D., & van der Veen, J. T. (2026). Secondary school teachers' experiences in extending education for sustainable development beyond their classrooms: A multiple-case study. *Teaching and Teacher Education*, *183*, Article 105811. Advance online publication. https://doi.org/10.1016/j.tate.2026.105811

Document license:
CC BY

DOI:
10.1016/j.tate.2026.105811

Document status and date:
E-pub ahead of print: 01/12/2026

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 16. Nov. 2026

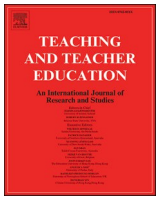
Teaching and Teacher Education 183 (2026) 105811



Contents lists available at ScienceDirect

Teaching and Teacher Education

journal homepage: www.elsevier.com/locate/tate



Research paper



Secondary school teachers' experiences in extending education for sustainable development beyond their classrooms: A multiple-case study

Tuba Stouthart *, Dury Bayram, Jan van der Veen

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

ARTICLE INFO

Keywords:
Education for sustainable development
Educational change
Teacher leadership

ABSTRACT

Secondary school teachers often struggle with implementing education for sustainable development in their classrooms. Research has identified several challenges, including adopting new teacher roles, and assessing complex learning outcomes. However, less is known about how teachers experience extending education for sustainable development beyond their classrooms. This multiple-case study explores teachers' experiences within a wider school context. The study involved seven teachers and three principals from three secondary schools in the Netherlands. Data were collected through interviews and field notes during a three-year professional development program. Findings show that *local characteristics*, including the school board, community, principal, and teachers, significantly shaped teachers' approach to education for sustainable development. The study highlights how leadership practices influence teachers' efforts in engaging their colleagues in education for sustainable development. The results further demonstrate how school-based curricular space is taken up by teachers as a means to extend education for sustainable development.

1. Introduction

Education for sustainable development (ESD) aims at equipping learners with the knowledge, skills, values, and attitudes needed to promote a sustainable future (UNESCO, 2020). However, challenges arise when addressing reform-oriented goals in education, including but not limited to ESD implementation in secondary schools (Chen & Xiao, 2021; Kinskey & Zeidler, 2021; Mulà & Tilbury, 2023). This is partly because ESD represents a departure from traditional, discipline-based and transmissive forms of teaching (Arntzen et al., 2025; Fischer et al., 2022; Forssten Seiser et al., 2023). At the classroom level, ESD calls on teachers to adopt new approaches to teaching, embracing the holism of sustainability across multiple school disciplines (Ariza et al., 2021; Uitto & Saloranta, 2017). As a result, teachers encounter a range of challenges in implementing ESD, including collaborating across disciplinary boundaries (Chen & Xiao, 2021; van Poeck et al., 2025), fostering action-oriented competences (Sass et al., 2024) and assessing complex learning outcomes (Stouthart et al., 2023; Tryggvason et al., 2022). Moreover, extending ESD beyond the classroom introduces additional complexity, as it requires changes in collaboration structures and how leadership is practiced between principal and teachers (Ghamrawi et al., 2025; Taskin-Ekici et al., 2025; Verhelst et al., 2021, 2024). In this study, extending ESD implementation beyond classrooms refers to an approach in which ESD is not confined to a single lesson or teacher, but extends beyond individual lessons, is explicitly supported by school leadership, and is recognized within school policies and practices (Wals & Mathie, 2022). Given that ESD implementation entails both pedagogical practices and organizational structures, it can be understood as a process of educational change. Fullan (2015) conceptualises educational change as the implementation of new practices across multiple levels of the education system, emphasizing the importance of collaboration, capacity building, and meaning making. Accordingly, ESD implementation is conceptualised in this study as a process of educational change, drawing on Fullan's (2015) framework.

Research emphasises that ESD implementation should be understood as a collective endeavour within school organization and leadership (Gericke & Torbjörnsson, 2022; Holst et al., 2024; Mogren & Gericke, 2017; Wals, 2006). At the same time, studies indicate that ESD implementation in schools is often driven by teachers who take initiative and assume leadership roles (Berglund et al., 2025; Daumiller et al., 2025; Miedijensky & Abramovich, 2019). Additionally, ESD is both ambitious and comprehensive (Forssten Seiser et al., 2023), leaving considerable

* Corresponding author. 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.
E-mail address: t.stouthart@tue.nl (T. Stouthart).

https://doi.org/10.1016/j.tate.2026.105811
Received 10 November 2025; Received in revised form 17 June 2026; Accepted 27 August 2026
Available online 8 September 2026
0742-051X/© 2026 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

room for how teachers interpret it and initiate its implementation. As a result, its enactment depends heavily on how teachers adapt ESD goals to their own contexts (Schutte et al., 2025b). However, little is known about how teachers experience extending ESD implementation beyond their own classrooms, despite their recognized role in driving and shaping ESD in practice.

Therefore, this study explores the experiences of seven teachers who extend ESD implementation beyond their classrooms at three Dutch secondary schools. The educational change pursued within each school is defined by teachers themselves through their participation in a cross-school professional learning community (PLC). Unlike typical reforms driven by external stakeholders, such as national curriculum changes, the PLC supported teachers in collaboratively designing and enacting change across disciplines and schools. As such, the change process is shaped by teachers' contextual realities and perceived needs. Additionally, the PLC supported teachers in taking on and enacting leadership roles in ESD implementation within their schools. This teacher-led, context-responsive approach allows us to frame the study as a multiple-case study, with each secondary school representing a distinct case.

By exploring teachers' experiences, the study contributes to a better understanding of the dynamic and the context-dependent nature of teacher-led ESD implementation at the school level, where teachers take a leading role in extending ESD implementation beyond their own classrooms. The findings offer insights into how teachers experience, navigate, and respond to challenges and enablers of leading change within their school contexts. These insights can inform teacher educators, professional development designers and school leaders to better support teachers as drivers of educational reform. Understanding teachers' contexts can inform the design of professional development programs that support teacher-led innovations effectively (Balgopal, 2020).

Fullan's (2015) educational change model is used as an analytical lens to examine teachers' experiences through three categories and nine factors in the framework (see Fig. 1). Given the qualitative, case-based nature of this study, the aim is not to generalize but to explore how the factors identified in Fullan's (2015) framework can help explain the ESD implementation in the cases studied. The study addresses the following research questions, where the term 'factors' refers to the conceptual factors influencing educational change as identified by Fullan, rather than to statistical factor analysis.

- What factors affect secondary school teachers' implementation of education for sustainable development at their schools?
- How does the influence of these factors unfold during the process of implementation?

An in-depth analysis of teachers' experiences is necessary to capture an account of *what* factors affect their implementation of educational change and *how* these factors promote or challenge them in doing so. By exploring the *what*, this study aims to identify which of these factors influence teachers' implementation of ESD-related educational change. By exploring the *how*, we seek to understand how these factors are manifested in practice, specifically whether particular factors emerge as enablers or as challenges. To our knowledge, no studies have used Fullan's (2015) educational change model to explore secondary school teachers' experiences in implementing educational change in the context of ESD.

1.1. Background and theoretical framework

1.1.1. Education for sustainable development (ESD)

The literature on ESD highlights the need for all educational stakeholders to prepare teachers to address sustainability-related issues in their lessons (Corres et al., 2024; Redman & Wiek, 2021; Scherak & Rieckmann, 2022). This aligns with the global urgency of Agenda 2030 (UNESCO, 2015), which recognises education as one of the 17 Sustainable Development Goals (SDGs), SDG4. While one approach to supporting teachers in implementing ESD is through curriculum-focused professional development, another is by facilitating teacher-led curriculum design, where teachers adapt their curricula to incorporate ESD (Isac et al., 2022; Schutte et al., 2025a; Stouthart et al., 2023). However, teachers' limited experience in leading change for sustainability education is regarded as a major barrier to mainstreaming ESD (Mulà & Tilbury, 2023). Additionally, local conditions such as school structures affect teachers' sense of ownership and capacity to sustain new teaching strategies (Priestley et al., 2012). As a result, ESD is enacted in diverse ways; some integrate it into the national curriculum, while others address it outside regular lessons (Scheie et al., 2025; Schutte et al., 2025b; Wals & Mathie, 2022).

As highlighted by UNESCO (2020), a whole-school approach is considered as an effective way to implement ESD in secondary schools. A holistic approach to ESD is appropriate where the school as an organization has the ability to enable ESD implementation (Wals et al., 2024). However, the current literature does not reveal how to translate this theoretical perspective into practice (Verhelst et al., 2024). Given that sustainability-related issues are inherently interdisciplinary (Zeidler,

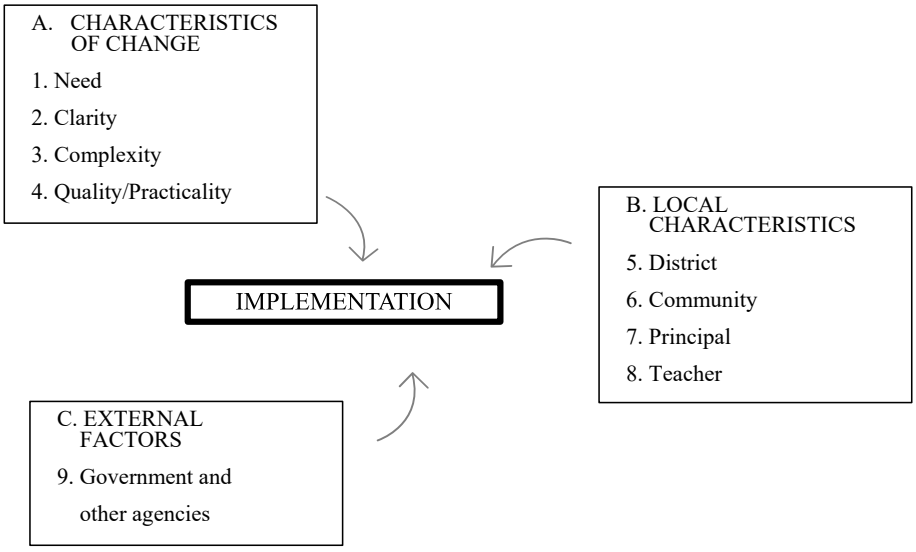


Fig. 1. Interactive factors affecting implementation of educational change (Fullan, 2015).

2014), it is important for school leaders to encourage and facilitate collaboration among teachers across various disciplines to balance the economic, social and environmental dimensions of sustainability (Ariza et al., 2021; Chen & Xiao, 2021). Achieving this balance presents significant challenges, since it requires not only teachers, but also schools to shift from education focused mainly on acquisition and application of knowledge to more progressive educational approaches that embrace moral intelligence and social responsibility (Zeidler & Sadler, 2023).

1.1.2. Educational change and teacher leadership

Change can be understood as a process of challenging existing practices, exploring and adopting new ways of working, and stabilizing the new situation. This process is captured in Lewin's three-stage model of change (Lewin, 1947), often described as freeze-change-refreeze. However, Lewin's conceptualization provides a general account of change processes (Burnes, 2004), and gives limited attention to how change is enacted in educational settings.

Fullan's (2015) model of change, on the other hand, was developed specifically for educational contexts and focuses on the complex, collaborative, and systematic nature of school improvement and educational reform. Comparable to Lewin's (1947) three-stage model of change, Fullan's (2015) model also describes change through three phases: *initiation, implementation,* and *institutionalization*. While *initiation* refers to the process that leads up to the decision to adopt a change, *implementation* involves the first experiences of attempting to put reform into practice. The final phase, *institutionalization,* refers to sustaining the change beyond the implementation phase at the institutional level. The implementation stage plays a crucial role, because it is how the desired objectives of the intended educational change are accomplished. According to this model of educational change, nine factors affect the *implementation* phase as shown in Fig. 1.

Fullan identified three categories of factors active in this phase, as shown in Fig. 1. The first relates to the characteristics of change: the perceived *need* for it among stakeholders; the *clarity* of its goals and processes for practitioners, such as secondary school teachers; the *complexity* of its implementation; and the *quality and practicality* of the change itself and the available support, such as the resources and training offered through the PLC. The second category includes local characteristics: the influence of previous reform efforts in the *district* or region; the role of the *community*, including the school board and broader social context; and the contributions of *principals* and *teachers* in driving or shaping change. The third category involves external factors such as *government bodies and agencies*, which influence implementation through curriculum.

Fullan's (2015) model offers a useful framework for understanding how educational change unfolds. It has been applied across diverse contexts, including technology integration in secondary schools (Bahçekapili, 2018), programming (Korhonen et al., 2023), curriculum reform in physical education (Ha et al., 2008), and inquiry-based science teaching (Gordon, 2024). These studies demonstrate the model's effectiveness in analysing reform processes. A consistent finding across such studies is that that teachers play a central role in the implementation of educational change. For example, Miedijensky and Abramovich (2019) showed that teachers' motives, roles and actions significantly shape the implementation of sustainability education.

Teachers are uniquely positioned to lead educational change, as they are directly responsible for classroom practice, the core site of teaching and learning (Fullan, 2015; York-Barr & Duke, 2004). In the context of ESD, progress typically stems from individual teachers' initiative, driven by bottom-up momentum. Top-down approaches, on the other hand, may result in weaker commitment in ESD implementation (Mogren et al., 2019). Change often begins with enthusiastic teachers forming a 'coalition of the willing', especially since ESD goals are rarely embedded in secondary curricula. In such settings, teacher leadership not only drives innovation but also contributes to professional growth among colleagues (Sinha & Hanuscin, 2017; Wenner & Campbell, 2017; York-Barr & Duke, 2004). Teacher leaders can play a pivotal role in implementing desired pedagogical practices by reshaping the school's vision for learning and teaching (Harris & Jones, 2019; Wilkie, 2025). Moreover, teachers' involvement in decision making is a key to improving school-based education (Lai & Cheung, 2015; Valdés Sánchez & Gutiérrez-Esteban, 2023) as effective educational change requires active engagement across all levels of an organization (Spillane et al., 2001). For example, leadership that is distributed between principals and teachers creates conditions for meaningful change (Cheng & Szeto, 2016; Oppi et al., 2023), and supports the ESD implementation (Bosevska & Kriewaldt, 2020). The interactions between principals and teachers who are in position to bring about a major change in how education is delivered are therefore crucial for educational change (Meyer & Slater-Brown, 2022; Reinius et al., 2022; Wenner & Campbell, 2017). Without the support of the principal and others in leadership positions, teachers' activities to implement change are unlikely to flourish (Chobphon, 2024; Muijs & Harris, 2006). School leaders are essential in creating the organizational conditions such as supporting collegial communities and time for teacher collaboration for ESD implementation (Mogren & Gericke, 2019). Organizational structures that empower meaningful teacher collaboration are essential for sustained school improvement (Ford & Youngs, 2018; Vermeir et al., 2017) and ESD implementation (Arntzen et al., 2025; Bosevska & Kriewaldt, 2020; Taskin-Ekici et al., 2025).

2. Method

2.1. Research design

This study adopts a multiple-case study design to explore ESD implementation through the lived experiences of teachers, drawing on a phenomenological approach (Creswell & Poth, 2018; Teherani et al., 2015). While individual teachers are positioned as key change agents, their secondary schools serve as three distinct cases. Following Yin's (2018, p.15) definition of a multiple-case study design, each case investigates a contemporary phenomenon, here ESD implementation, within its real-world context, here three different secondary schools in the Netherlands. The multiple-case study design enables a comparative analysis of how the nine factors associated with the implementation phase identified in Fullan's (2015) educational change model, as shown in Fig. 1, influence ESD implementation across different school contexts.

2.2. Context

This study was conducted as part of a 3-year collaboration between a consortium of secondary schools and the researchers' institution, starting in 2022. As part of this partnership, a cross-school professional learning community (PLC) was established as a regional driver of change to support teachers in initiating ESD implementation through challenge-based learning and developing the associated lesson materials. Teachers' participation in the PLC was initiated and supported by their principal. The literature suggests that sustained collaboration across schools, in which teachers systematically learn from and with each other, can reduce resistance to change and foster innovation (Binkhorst et al., 2022; van Driel et al., 2001).

In the Netherlands, where this study is positioned, the secondary school curriculum is highly decentralised, giving schools and teachers significant autonomy in shaping their local curriculum (Nieveen & Kuiper, 2012). This flexibility is referred to as *ontwerpruimte*, or 'design space', emphasizing the role schools and teachers take in shaping their school-based curricular activities (SLO, 2022). This flexibility, however, often makes it challenging for teachers to use that space effectively in practice (Handelzalts et al., 2019). These contextual realities justify our focus on teachers as change agents in their role as curriculum designers (Ellingson, 2018; Huizinga et al., 2014; Stouthart et al., 2023), and on teacher collaboration in a PLC setting as a key

strategy for educational change (Handelzalts et al., 2019; Onderwijsraad, 2017).

Over the course of the three-year program, eight PLC meetings were held per year, each lasting 3 h. The role of the PLC evolved in response to the changing needs of participating teachers. This included, for example, sessions with invited experts on topics such as socioscientific issues, and challenge-based learning. In addition, students and school leaders were invited to participate in some PLC sessions to support teachers' implementation. These contributions were incorporated in response to emerging insights into the roles of students and school leaders in the implementation process, reflecting the PLC's dual role as context and an adaptive intervention.

In the first year of the PLC, the focus was on building teachers' pedagogical design capacity to empower them as re-designers of their curricula in order to implement ESD (Stouthart et al., 2023). While teachers set goals for ESD implementation in their own schools, they also developed lesson materials collaboratively and exchanged feedback. They built foundational knowledge using literature and frameworks relevant to ESD implementation. In the second year, teachers piloted their lesson designs in classrooms, refined them, and engaged in deeper discussions about pedagogical strategies to address ESD. Some formed school-based teacher groups to continue the work initiated by the PLC in their own school contexts. In the final year, the focus shifted from teachers' own classroom experiences to sustaining and scaling up the change. Teachers worked on engaging colleagues within their schools, aiming for broader institutionalization of ESD practices.

2.3. Participants

Secondary schools in the region of Eindhoven were invited to participate in a cross-school PLC. Three regular Dutch secondary schools joined the PLC, which we examine as Case I, Case II and Case III, shown in Table 1 below. Our study used purposeful sampling (Creswell & Poth, 2018), involving seven teachers from the participating schools, six of whom volunteered to join the PLC meetings. Each participant in the PLC was allocated 80 h per year to support their engagement. The remaining teacher, referred to as Kim in Table 1, did not participate in the PLC, but was included in the study due to her active role in ESD implementation at her school. Additionally, school principals were also included as participants in this study, even though they did not take part in the PLC, due to their role in participant teachers' ESD implementation. Table 1 presents demographic information for the participant teachers, and the focus of the ESD implementation for each case/school. Teachers' names provided in this table are pseudonyms.

Table 1
Demographic data for participant teachers.

Case	Name	Subject	Years of teaching experience	Focus of ESD implementation
I	Bas	Physics	11	Creating alignment between physics and arts curricula with respect to approaches to teaching and learning in ESD
	Daan[a]	Arts	26	
II	Floris	Biology	5	Embedding the SDGs into school-based curricular activities, and expanding this integration to the entire school curriculum
	Max[a]	Geography and Global Issues	9	
III	Twan	Physics	15	Developing a didactic method to be used for interdisciplinary teaching in both lower and upper secondary classes
	Kim[b]	Biology	11	
	Milan[a]	Arts and Global Perspectives	7	

[a] Participants who joined the PLC in the second year and continued thereafter.
[b] The participant who was not part of the PLC, but was interviewed for data collection.

In the first year, Bas, Floris, and Twan joined the PLC, each working at a different school. After reflecting on the challenges teachers faced during the first year of the PLC, we invited at least one additional teacher from each school to join the PLC for the remainder of the program. This decision aligned with research showing that teacher-led educational change is more effectively supported when multiple teachers from the same school participate in a PLC (Fitzgerald et al., 2019). Therefore, Daan, Max, and Milan joined voluntarily in the second year. One teacher, Kim, did not participate in the PLC due to workload constraints, but was included in the study through interviews and focus group meetings at her school, given her role in ESD implementation.

2.4. Data collection

In this study, interviews with teachers, field notes from participant-observation of PLC meetings, and teachers' focus group meetings at their schools were used as primary sources of evidence. Additionally, lesson observations, lesson materials, researchers' field notes, and documents such as school vision statements were used as secondary sources of data. Although the primary focus was on teachers' experiences, the need to include principals' perspectives emerged during the first cycle of data analysis. Their insights proved essential for gaining a more balanced and comprehensive understanding of teachers' implementation process. Therefore, one principal from each of the three secondary schools was interviewed, allowing us to capture their perspective and reach a complete understanding of ESD implementation.

2.4.1. Interviews

Two interview techniques were used in this study: semi-structured interviews and informal conversational interviews. A semi-structured interview guide for teachers was developed after the first year of the program, informed by challenges identified in the literature and observations from PLC meetings. These individual interviews were conducted during the second year of the program. A separate semi-structured interview guide for principals was developed in response to the emerging findings. These interviews took place at the end of the PLC program.

Semi-structured interviews were conducted by the first author at the secondary schools of the participating teachers and principals. Each interview lasted approximately 1 h and was audio-recorded and transcribed verbatim. Although the interviews were conducted in English, participants occasionally used Dutch, and those sections were translated into English.

Ad hoc individual and group interviews with teachers were conducted in informal, conversational settings throughout the program. These interviews helped the researcher stay informed about the implementation process at each school. For example, group interviews were held when PLC participants collaborated with colleagues at their own schools who were not part of the PLC. It was during such an informal setting that Kim, who was not a PLC participant, became involved in the study. Additional informal interviews took place during school visits, both before and after lesson observations. These settings allowed participants to express themselves authentically, offering insights into their perspectives and the case-specific experiences (Patton, 2015).

2.5. Data analysis

While the study draws on phenomenology to foreground teachers' lived experiences, the analysis was guided by Fullan's (2015) educational change framework as the use of theoretical propositions is considered an effective approach for data analysis in case study research (Yin, 2018, p. 168). Data were analysed by using both inductive and deductive approaches. Firstly, open coding was used to break down the data and generate codes inductively (Boeije, 2009), with coding conducted independently of the theoretical framework. The data were coded inductively through an iterative process via ATLAS.ti (qualitative

data analysis software). Each code was then interpreted and assigned to the most relevant sub-category within Fullan's (2015) framework. Coding structure was developed deductively based on the three categories and nine factors identified in his framework (see Fig. 1). The final codebook, resulting from both inductive and deductive coding, is provided in the Appendix, in Table A1.

Importantly, codes were not forced into the predefined structure; rather, all code segments could be meaningfully interpreted within the framework. In applying the framework, however, some adaptations were made. For example, while Fullan identifies *government and other agencies* as a factor (see Fig. 1), our data indicated that *curriculum* was the only relevant influence within the category of external factors. Accordingly, the factor *government and other agencies* was renamed as *curriculum* to reflect this (see Appendix, Table A1). In addition, inductively generated codes such as *colleagues* and *students* were interpreted as part of the broader sub-category of *community*. This reflects the conceptualization of *community* as encompassing the network of actors within the local context.

After completing the coding process, all coded segments were revisited iteratively to develop an overall understanding of the data. This interpretive step involved an in-depth reading of the coded material, focusing on the richness and explanatory relevance of the data in relation to the research questions, rather than on the frequency of occurrence of codes (Miles & Huberman, 1994). Through this process, it became apparent that the factors *quality/practicality of the professional development program*, *community*, and *principal* emerged as particularly salient in capturing the most meaningful and analytically relevant aspects in the data. While the remaining factors were present in teachers' experiences, these three offered the greatest interpretive relevance in addressing the research questions.

Consistency between the first two authors was supported through collaborative coding discussions. After the first author coded an interview, both authors met regularly to review and discuss the coding decisions, refining the codebook and ensuring agreement (Creswell & Poth, 2018; Miles & Huberman, 1994). To ensure trustworthiness, member checking was conducted with a participating teacher from each school, who reviewed the draft case study report.

3. Results

In this study we aimed at exploring what factors affect teachers' ESD implementation beyond their classrooms and explaining how these factors unfold in three secondary schools. To answer our research questions, we used Fullan's (2015) educational change model, identifying the nine factors that can affect implementation (see Fig. 1). In our case studies, three of those factors were at the forefront: *quality/practicality of the professional development program*, *community*, and *principal*. For this reason, our results section focuses on explaining how these factors influenced teachers' implementation. We elaborate further on why these factors appeared more salient in our data than the others in the discussion section.

In the following section, we present our within-case results, focusing on how the factors of *quality/practicality of the professional development program*, *community*, and *principal* affected teachers' implementation at each school. By presenting the results in this way, we highlight case-specific local characteristics and examine in detail how these characteristics influenced teachers' approach to ESD implementation.

3.1. Case I: Combining sciences and arts perspectives

Bas designed and implemented a unit on Energy for VWO 3 class (students aged 14-15), integrating SDG-7, affordable and clean energy. Daan, who taught Arts in VWO 4, joined the PLC in the second year of the program, where they worked together to create vertical alignment between their subjects. Their goal was that the ESD themes and approaches to teaching and learning introduced in physics classes by Bas would be built upon and extended by Daan in the following year from the arts perspective.

Our analysis revealed that these two teachers focused on coordinating their own classes and by doing so, they limited their need to interact with other colleagues. This, in turn, limited the dissemination of their implementation to their colleagues. While the individual goal pursued by Bas and Daan was centred on aligning their subjects, the PLC focused on ESD implementation beyond their classrooms, and lesson design. This is illustrated in Fig. 2 below.

The teachers' primary focus on their own subjects led to limited engagement with colleagues and the principal, thereby highlighting the influence of the *community* factor. Engaging colleagues in the process and encouraging them to implement ESD in their lessons was one of the key challenges Bas and Daan faced. While Bas appreciated the *quality/practicality* of how PLC was designed to facilitate developing lesson materials, he had challenges in terms of time management and collaboration within the PLC. How these two factors, *community* and *quality/practicality of the professional development program,* affected their implementation is elaborated in the following sections below.

3.1.1. Engaging colleagues: 'I am just a teacher; I am not a salesman'

This section elaborates on how *community* as a factor affected the teachers' implementation. While Bas recognized the importance of involving his colleagues for ESD implementation, he regarded it as a considerable responsibility for himself. He did not know if any of his colleagues were interested in implementing ESD or had done so at any level. He also expressed uncertainty about how to extend ESD implementation across the school, and he emphasized the need for another party to take on this responsibility. He experienced the lack of a supportive *community* to achieve this goal, and suggested that it would have helped if the organizers of the PLC program had taken responsibility for ensuring that more of his colleagues participated in the process, thereby promoting ESD implementation.

> That would help me if there would be a way of getting more teachers involved because now, I have the feeling that I'm working on my own over here. I don't have any clue how to spread it over the school. It would be nice if that part would be taken care of. … it would be nice if that would come from the PLC or whatever. Because now everything is on my shoulders. (Bas)

The interview with the school principal revealed that Bas's participation in the PLC was supported primarily as an opportunity for his own professional growth, and that Bas was able to interact with his colleagues from the science department regarding the lessons he designed and implemented. However, encouraging the participation of teachers from other departments or the ESD implementation beyond individual classrooms was not considered by the principal.

> It started as an opportunity for [Bas] personally to see what he could do in his lessons. … and looking back at it, it's almost a pity because I think if that would have been a choice from the school itself, like, okay, this is something that we know or believe in or want to embrace in our educational system, I would probably have asked some other teachers from other areas to participate. I didn't. (Principal)

Bas compared the role of promoting the involvement of other teachers to that of a salesman, saying that it would feel like selling a product to his colleagues if he tried to get them involved. Bas perceived this role as difficult for a teacher to fulfil, showing that he found it challenging to change the norms for interacting with his colleagues.

> I am just a teacher; I am not a salesman … that's not me. We were talking about that last meeting, that it is difficult for us as teachers to make this project bigger and implement it over a bigger part of the school. (Bas)

According to Daan, if they could figure out how to implement ESD for

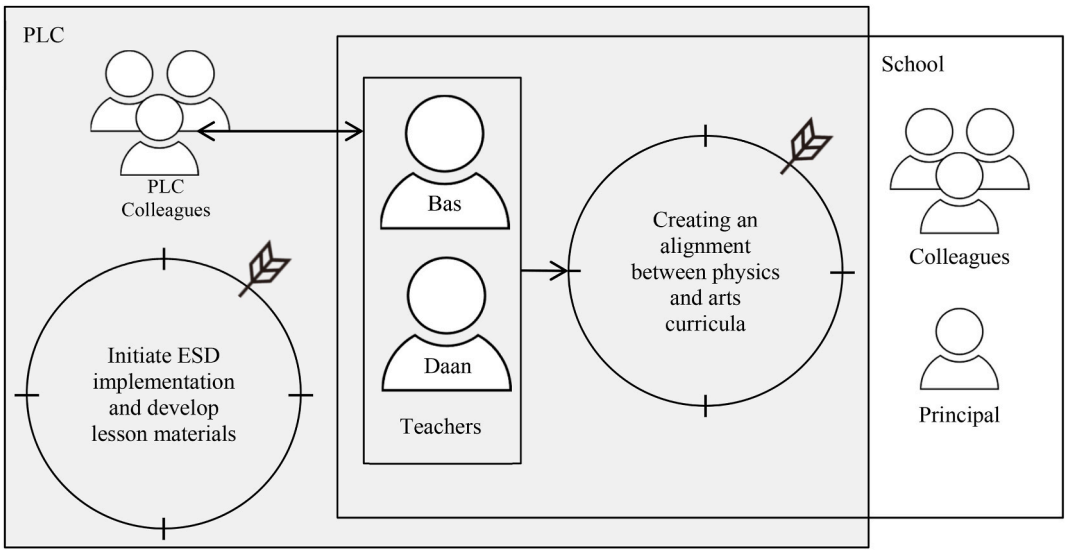


Fig. 2. Relationships between PLC goal, teachers' goal, and the school context in Case I.

their colleagues, it would be as if they had created a clear, simple plan that could be handed over to other teachers. This would allow their colleagues to implement ESD with little effort. This showed that Daan embraced the responsibility reflecting a sense of agency for implementing ESD. Daan said that if they wanted to involve other teachers in the process, it should not require much effort on teachers' part. Since Daan and Bas were the ones receiving hours for implementing ESD and having their participation in the PLC facilitated by their school, Daan held himself and Bas responsible for doing the work for their colleagues to engage them, ensuring that it did not require much effort from them.

> If they [his colleagues] put in less effort, and we [Bas and himself] work it out for them, because we get hours, that is maximum profit, I think. So, if we do that, it is better. (Daan)

The principal recognized the challenge of involving other teachers in the process from the perspective of teachers. She emphasized that teachers' main task is to provide education in their class, and she recognized that teachers need more support to achieve a change beyond their classrooms.

> In general, teachers find it quite difficult to see in the school organisation level how they could upscale something. And it's not strange because they are in the classroom for 80% of their time. (Principal)

3.1.2. The role of the PLC

Another factor at play in this case, as revealed by our analysis, was the PLC program's *quality/practicality*. Teachers had 80 h allocated in their annual contract for their participation in the PLC. Bas explained that he always spent more time designing lessons, creating activities, worksheets and other materials, than he was paid for. When the PLC opportunity became available, he saw it as a way to finally receive compensation for what he would have done anyway. His primary motivation was not the PLC's focus on ESD, but the structured time it offered for improving educational quality, which he saw as a valuable opportunity to get rewarded for his work.

> My goal was, this was not my goal, but I received actual hours for creating something. Normally, I create everything in my own time, and that's fine by me, but now there was an option, creating stuff and getting paid for it. (Bas)

Bas appreciated the PLC for providing time to design his lessons, but found the first-year meetings challenging, because they were focused on theory-building and developing teachers' pedagogical design capacity for ESD. He did not find the expert-led lectures or presentations particularly valuable, as he would have preferred to spend that time designing lessons. Once he was working together with Daan, they had a focused and practical goal, whereas the goal of the PLC was broad and ambitious. Additionally, Bas was not engaged by the assigned literature, stating, 'There were some articles that we should read, and that is not my stuff'. Instead, he preferred to implement ESD by experimenting directly in his teaching practice, learning through doing, reflecting and adjusting, rather than relying on research or expert guidance, showing the mismatch with practicality of the PLC's goal.

While Bas appreciated the opportunity to collaborate with enthusiastic and innovative teachers in the PLC, he found it frustrating that the meetings did not focus more on collaborative lesson design. He valued collaboration with others because he lacked such an opportunity within his school. His colleague Daan, who also participated in the PLC, also did not have time for collaboration outside PLC meetings.

3.2. Case II: linking existing school-based curricular activities with the SDGs

Floris and Max worked at a school that offers school-based curricular activities through project weeks and choice hours. Three times a year, regular lessons are suspended for project weeks, during which students engage in teacher-led projects focused on skill development rather than content knowledge. In addition, students have a weekly choice hour, where they can select from various teacher-supervised activities, such as chess. Teachers have full autonomy to design these school-based curricular activities and are not bound to specific subjects or national curricula. During the program, Floris created escape rooms themed around the SDGs, while Max adapted his existing project, 'How privileged am I?', to incorporate the SDGs.

Our analysis showed that the school *community* played a key role in these teachers' ESD implementation efforts. Floris and Max began by creating an inventory of all existing school-based curricular activities and mapping their connections with the SDGs, aiming to initiate the integration of the SDGs across the entire school curriculum. This is illustrated in Fig. 3 below.

Throughout the program, Floris and Max regularly shared their work with colleagues, such as during team meetings. These interactions allowed them to form a dedicated teacher group within their school to pursue their goal. Moreover, meetings with the principal helped them refine their vision and solidify their plans, which we saw as reflecting the influence of the factor *principal*. The following sections therefore explore

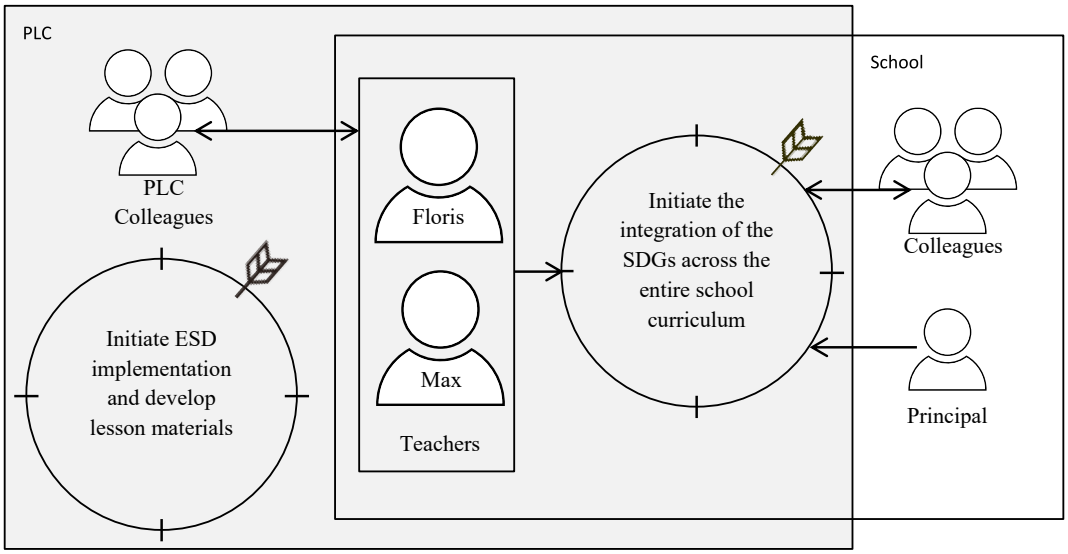


Fig. 3. Relationships between PLC goal, teachers' goal, and the school context in Case II.

how the school community, particularly school-based curricular activities, and the principal contributed to implementing ESD.

3.2.1. School-based curricular activities

Floris believed that presenting ESD as an educational change might discourage colleagues, who could resist due to its novelty and the extra time and effort involved. Instead, he and Max focused on existing school-based curricular activities, viewing the autonomy teachers had in designing these as an opportunity for ESD implementation showing the role of the school's structure and *community* in enabling change. They created an inventory of existing activities and mapped their connections with the SDGs, framing this work as aligning current practices rather than introducing something new. This approach allowed colleagues to see ESD as already embedded in their work, reinforcing their sense of agency and avoiding the perception of an imposed initiative.

> For now, it's like, we don't call it change, it's keeping things the same, we don't want to change because there's a lot of change going on already, and you don't want to lose people. … we start with this overall view of what projects there are, and how they are maybe connected to SDGs, instead of saying you do this project, connect them to the SDGs, that doesn't work. (Floris)

Max believed that many existing projects were already aligned with the SDGs, but the connection was not explicit, and teachers were unaware of it. In addition to creating an inventory of these projects and their alignment with the SDGs, Floris and Max raised awareness among their colleagues by organising a workshop so that future initiatives would be intentionally linked with the SDGs.

Floris and Max emphasized that activities during project weeks lacked cohesion, as each teacher designed their own project independently. They felt that this lack of cohesion made the project weeks less meaningful for students, since regular lessons were replaced by disconnected projects. To address this, they proposed using the SDGs as an overarching theme to create meaningful connections between projects. By making these links explicit, they aimed to enhance the relevance of the projects for students.

> We want to go for the SDGs as a framework. Framework for all these different projects that have been held and done here and there. And for now, it's not really visible for the students that they do something with all these SDGs. (Floris)

3.2.2. Principal's support in engaging colleagues

Floris observed that various teacher groups at his secondary school were addressing societal challenges in how they designed activities, but often in isolation. He formed a dedicated group of teachers within his school, recognizing the potential for greater impact through collaboration. He envisioned such collaboration among teacher groups as a continuation of the PLC's work, with their school team adopting the same focus. The initiatives led by Floris and Max helped shift the school culture from isolated practices to more collaborative interactions.

> … there are all different groups, different persons in school, and different smaller groups, bigger groups … they're all doing something to change. And it's all islands. So, I also said to [principal], maybe it's an idea to bring them together. … now this change comes from different parts, and it's nice to have that, like, joined. (Floris)

With the principal's support, Floris and Max organised a workshop for their colleagues to introduce the SDGs and explore their integration into the curriculum. Their aim was to inspire the formation of a school-based group focused on implementing ESD. The session helped Floris and Max identify teachers interested in joining them in this effort. Ultimately, they envisioned a stronger group also involving management and students. Recognizing the interdisciplinary nature of sustainability issues, they saw value in forming a cross-subject team with diverse stakeholders to enrich the school's curriculum.

> We started with a group of almost only teachers, and I think it's quite important to make it a bit diverse maybe, so also [including] a teacher leader, or a head of school … to make it more diverse, because we're working in one layer of the hierarchy now. (Floris)

> If you consider, like the work group that we've now kind of assembled, are mostly teachers that are either biology, science, geography. … the goal is that you also get this message to, let's say, a language teacher, where you don't automatically see the SDG framework connected to their projects. (Max)

Floris and Max received strong support from their principal to integrate the SDGs into the school curriculum. To help form a teacher group, the principal embedded the SDGs into school policy, complementing their bottom-up initiative with top-down support. This alignment strengthened their case when recruiting teachers, as SDG integration became a formal part of school policy rather than an optional effort for interested teachers only.

> My part was then to make SDGs an important part in our policy. In next year's policy, it says clearly that SDGs and sustainability is an important part of our education. That was my biggest contribution for them [Floris and Max], so they could say it's part of the policy. (Principal)

Another contribution to Floris and Max's efforts came from the school's structure and *community*, which allocated a development fund for teachers innovating their teaching practices. Beyond the principal's support, the availability of this fund highlighted the school's commitment to curriculum development and educational innovation.

3.3. Case III: A new teaching approach for ESD

Twan initially aimed to design an elective subject for upper-secondary students focused on learning in authentic contexts. To further develop this idea, he formed a school-based group together with Milan and Kim in the second year of the PLC. With input from colleagues and the principal, their work evolved into designing a didactic approach for both upper and lower secondary levels, adaptable across subject-matter disciplines. This approach introduced authentic issues into teaching and required collaboration between teachers from different subject disciplines, enabling students to engage with multiple perspectives within a single unit. This is illustrated in Fig. 4 below.

Their approach required at least two subject-matter teachers to co-develop an interdisciplinary unit addressing authentic issues, aligned with ESD principles. This process inherently depended on collaboration with and among colleagues. We viewed this as the influence of the school *community* factor in Fullan's (2015) framework. At the same time, the principal played a dual role: offering support that enabled progress, while also presenting constraints. These dynamics reflect Fullan's view that both collegial relationships and school principal are central to driving and shaping educational innovation. The following sections therefore explore how these two factors shaped the development and implementation of teachers' approach.

3.3.1. The Principal's role: between help and hindrance

Throughout the program, Twan, Milan, and Kim organized several sessions to present and refine their goal in dialogue with their colleagues. These interactions helped them revisit and sharpen their vision, recognizing the input and engagement of colleagues as crucial. However, Twan believed that for this vision to be adopted by teachers, it was essential for the principal to make her support visible. The principal attended the first inspiration session and stood alongside him, as requested by Twan. He believed that her visible presence would convey to colleagues that the initiative was supported by leadership and carried institutional importance. This moment reflected both the principal's supportive role and Twan's belief in her influence as a key factor in shaping interactions with colleagues.

> I said, 'Hey, if we're going to present this, I want you [principal] by our side. You have to be standing next to me.' Because it's not something that I, you know, Twan, who the hell am I, that I want. This is something that you support as a principal, as our school leader. (Twan)

In one of the sessions, attendance was lower than Twan had anticipated. He reflected that more colleagues might have participated if the invitation had come from the principal rather than himself, as his invitation was not taken seriously. Twan also noted that their didactic approach was dismissed by some colleagues. who referred to it as the 'Milan-Kim-Twan Show'. Many assumed the design was intended only for physics, Twan's subject.

> The one that sent the invite for this meeting was me. So, my colleagues, they have the perception, 'Oh, this is the thing that Twan has been working on for a couple of years. … It's not for me, I don't have to be there'. So, people had the impression that this was the, you know, the Milan-Kim-Twan Show. (Twan)

Twan and Milan struggled to align their expectations with the principal's level of involvement. While both the teachers and the principal recognized the importance of involving team leaders, there was no clear agreement on who was responsible for engaging them. Milan interpreted the principal's stance as assigning responsibility to the teachers, which he disagreed with. He emphasized that the principal should actively participate as part of her leadership role and considered it unfair for teachers to bear sole responsibility for securing team leaders' support.

> In every leadership course it is clear, if you want something from someone, do make that person part of the project. So that's what we should do, but [team leaders] should have some motivation to engage. … I find it strange that our principal believes in this, while at the same time she assumes that we as teachers should be the ones to convince the team leaders. (Milan)

On the other hand, the principal believed it was important that teachers themselves led the process of engaging their colleagues, including team leaders. She felt that teachers, as practitioners with direct classroom experience, were best positioned to speak about the

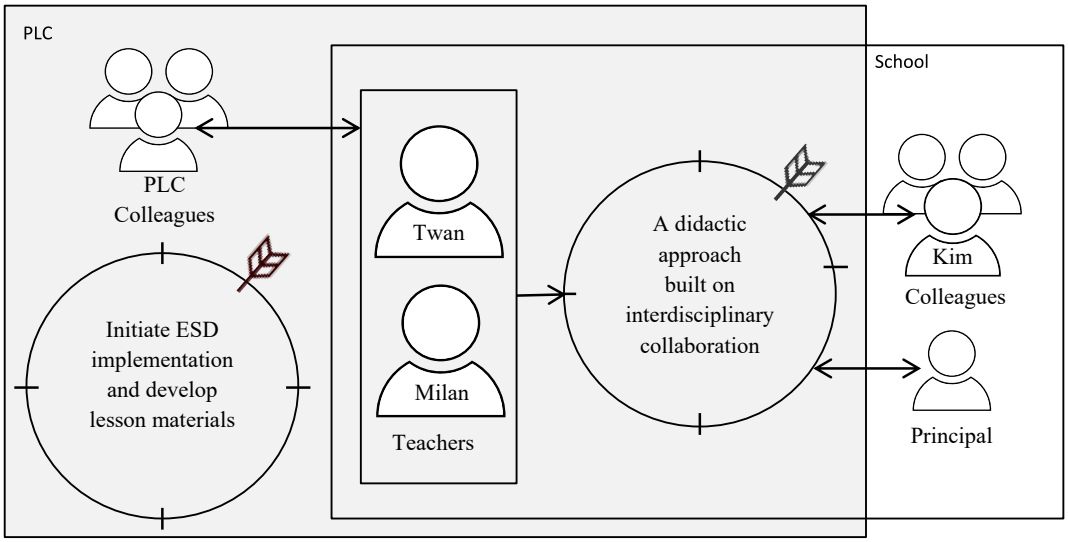


Fig. 4. Relationships between PLC goal, teachers' goal, and the school context in Case III.

didactic approach and its relevance. Despite her own teaching background, she noted that her position as principal could make it harder for her to be taken seriously when proposing teaching approaches to staff.

> I think it's important that the teachers, the group of Twan, that they are telling the teachers what the success is, and not the director. Because when we tell it, everybody thinks 'Yeah, okay, so what, you're not teaching'. (Principal)

3.3.2. *Recognizing ESD lesson design as a distinct teacher task*

After several sessions with colleagues, Twan, Kim and Milan identified a group of teachers eager to co-design an interdisciplinary unit using the didactic approach. While they succeeded in meaningfully shifting the norms of interactions among colleagues to foster collaboration, the participating teachers also requested dedicated hours for lesson design. They viewed cross-subject collaboration and joint implementation as beyond their regular duties, and felt they should be compensated for the additional work.

> … what they told me was a couple of things. They would like to get recognition, and recognition in terms of, you know, it actually boils down to be getting paid to do this. (Twan)

Twan brought this to the principal, but was reminded that teachers already have hours allocated in their contracts for lesson preparation and professional development. From the school management's perspective, designing lessons in collaboration could be framed as part of teachers' regular duties. Twan, however, perceived this as a challenge. He felt that co-creating an interdisciplinary unit went beyond standard lesson preparation, and his colleagues also viewed this as new and additional to their usual responsibilities. Twan believed that framing it as part of the existing workload would be demotivating and could discourage participation. His concerns highlighted the perceived importance of financially acknowledging the extra effort involved in adopting new approaches to teaching in educational change.

> We also explained to the school management; they were kind of arguing this just as part of your preparation that you normally do. … I said, but this is more than just preparing your lesson, you're asking a lot more from our colleagues because they can still prepare their lessons on their own and be a good teacher. … The argument that they use is, you are already paid, and professional development and preparing lessons is included, but this is different. (Twan)

Another challenge for teachers was finding time for collaborative lesson design. The didactic approach required at least two teachers from different subjects to work together, along with Twan, Kim or Milan. The principal suggested using Tuesday afternoons, which were free of teaching duties. However, department meetings were often scheduled during that time. For teachers such as Milan, who belonged to multiple departments, this created a conflict, forcing them to choose between meetings. Based on his experience, Milan opposed scheduling design sessions on Tuesday afternoons, viewing it as a professional disruption. He emphasized the need to revise the timetable to support interdisciplinary collaboration.

4. Discussion

This study explores factors influencing teachers' implementation of educational change in the context of ESD across three secondary schools. Drawing on Fullan's (2015) framework, three factors emerged as most influential: the *quality/practicality of the PLC program*, *community*, and *principal*.

In this study, teachers were supported by the PLC aimed at facilitating the initiation of ESD implementation beyond individual classrooms. Teachers' participation in the PLC was initiated and supported by their principals, aligning with the PLC's focus. Despite this shared support structure and common goal, teachers' approaches to ESD implementation differed across cases. We argue that one explanation for this variation is that the nature of the change was defined by the teachers in the PLC, rather than imposed externally through, for example, a national curriculum reform. Another explanation is that ESD is a broad and ambitious concept; as teachers made sense of it, their approach to ESD was shaped by their specific contextual realities. This illustrates how the change needed in the context of ESD can be enacted in diverse, context specific ways when defined by teachers. As a result, the teacher-led definition of change shaped which factors from Fullan's (2015) framework were most influential in teachers' approaches to ESD implementation, as summarised in Table 2 below.

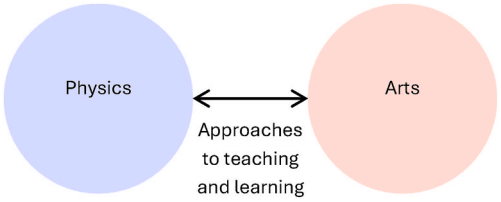
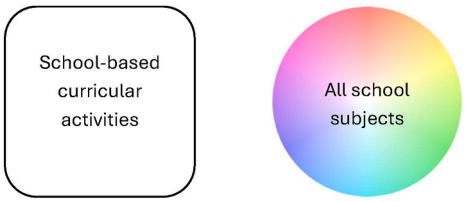
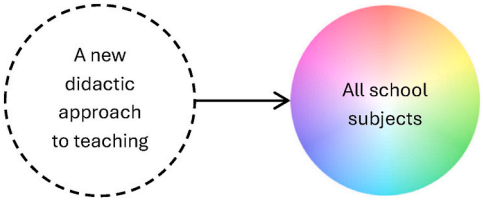
As shown in Table 2, teachers' approach to ESD implementation differed across cases. This is not surprising given that ESD implementation is inherently context-dependent (Wals & Mathie, 2022). We argue that the variations may be due to differences in teacher goals, school communities, and leadership approaches which led to distinct approaches to ESD. In Case I, teachers emphasized subject-specific alignment, keeping implementation within and between their own disciplines. In Case II, teachers integrated SDGs in school-based curricular activities, resulting in an approach disconnected from subjects. In Case III, teachers fostered interdisciplinary co-design and co-teaching within school subjects. Having provided this overview, the following sections detail how the three key factors, *quality/practicality of the PLC program*, *community*, and *principal*, played out across the cases.

4.1. *When PLC goals meet school realities: distributed leadership and expectations*

Our findings show that ESD implementation beyond individual classrooms is closely linked with the nature of the collaboration between teachers and principals. In Case III, Twan's coordination with the principal enabled shared leadership, where implementing educational change could be co-enacted by different stakeholders (Spillane et al., 2001). However, disagreements over responsibilities, such as engagement of team leaders, reflected that Twan and his principal had different role expectations. This suggests that establishing clearly defined roles is important when teachers are expected to lead change beyond their classrooms. Our study contributes to existing literature showing that teachers and principals have a limited understanding of teacher leadership (Oppi et al., 2023), and clearly defined roles and responsibilities are needed for teachers to act as change agents (Lai & Cheung, 2015; Meyer & Slater-Brown, 2022; Wenner & Campbell, 2017).

In contrast to Case III, Case I revealed limited collaboration between teachers and the principal. Bas, for example, implemented changes in his own practice, but did not see engaging colleagues in the process as part of his role, comparing such efforts to being a salesman. Our study aligns with previous literature showing that teachers' own perceptions of their role can hinder them in fulfilling it when it comes to educational change (Meyer & Slater-Brown, 2022). Although the PLC aimed to foster ESD implementation beyond individual classrooms, our results show that its purpose was not always clear to participant teachers or principals. Bas found the theoretical focus unhelpful and preferred time for collaborative lesson design. Previous literature has shown that in the context of teacher training for educational change, teachers need time during the training sessions to develop their own lessons that follow the reform-oriented goals (Bahçekapili, 2018). Our results show that without time and support within schools to apply PLC ideas, teachers may struggle to enact change beyond their own classrooms (Fitzgerald et al., 2019). These findings suggest that the PLC could have better clarified expectations and roles for both teachers and school leaders. Consistent with previous literature, our PLC could have better supported teacher leadership development by helping teachers align their beliefs, actions, and identities (Sinha & Hanuscin, 2017). To address these issues, future PLCs should explicitly define the shared responsibilities of each stakeholder (Bahçekapili, 2018). Moreover, future PLCs should work closely with school management to ensure that ideas developed in

Table 2
Salient factors from Fullan's (2015) framework and different approaches to ESD implementation across three cases.

Case	Key factors	Approach to ESD implementation	Visualization
I: Combining sciences and arts perspectives	***Community*: Limited collegial interaction** ***Quality/Practicality* of the PLC:** Focus on lesson design	Subject-specific implementation	
II: Linking existing school-based curricular activities with the SDGs	***Community*:** Strong collegial interaction, dedicated curricular space ***Principal*:** Policy support and enabling teachers to engage colleagues	Curricular implementation disconnected from school subjects	
III: A new teaching approach for ESD	***Community*:** Strong interdisciplinary ambition, but need for financial recognition and time allocation ***Principal*:** Support for teachers, but lack of coordination and role clarity	Cross-curricular implementation	

the PLC are supported and implemented in practice. To sustain such efforts, teacher education programs should provide professional development that prepares teachers to take on leadership roles in educational change.

4.2. The role of collegial interactions

Our results emphasize how collaborative communities play a role in extending ESD implementation beyond individual classrooms. In Cases II and III, teachers built strong internal communities that helped spread enthusiasm and sustain engagement with ESD. These collegial interactions enabled the dissemination of ideas from PLC meetings and maintained momentum beyond the PLC itself. This finding aligns with research on ESD, which shows that strong collegial interactions among teachers are crucial for implementation of bottom-up initiatives (Mogren & Gericke, 2017). In the broader literature, these findings support existing research emphasizing the importance of collaborative school culture for school improvement and innovation (Harris & Jones, 2019; York-Barr & Duke, 2004), and the role of teacher networks in enhancing capacity for curricular reform (Balgopal, 2020).

In contrast, teachers in Case I demonstrated the limitations of working in isolation. Without a dedicated peer group, Bas and Daan struggled to extend the implementation beyond their classrooms. This aligns with previous literature showing that a lack of organizational support for collaboration can hinder teachers from taking on leadership roles or driving change at the school level (Ford & Youngs, 2018; Muijs & Harris, 2006; Oppi et al., 2023). When teachers innovate but lack support, especially from school leadership, to build collegial networks, their efforts often remain confined to their classroom (Reinius et al., 2022).

Establishing norms for collaboration, such as creating time and space for teachers to work together, is crucial for educational improvement (Spillane et al., 2001) and ESD implementation (Arntzen et al., 2025). A proactive leadership style is needed to create the conditions that support collegial interaction in ESD implementation (Mogren & Gericke, 2019). Collective efficacy is an important factor affecting the success of teacher leadership in educational change (Harris & Jones, 2019), particularly in the context of ESD, where the societal issues are inherently interdisciplinary (Chen & Xiao, 2021; Zeidler & Sadler, 2023). In Case III, Twan, Milan, and Kim worked to overcome scheduling barriers with their principal to enable cross-disciplinary collaboration. This underscores the importance of school leaders providing environments where teachers from different disciplines can co-design interdisciplinary units to address ESD. A key contribution of our study is the recognition that leading educational change in ESD requires teacher collaboration across subjects. Given the multifaceted nature of sustainability issues, schools must provide time within teachers' regular schedules to support joint planning and implementation. Furthermore, to ensure long-term impact, this collaborative mindset should be cultivated early on. Teacher preparation programs should therefore support pre-service teachers in developing interdisciplinary lesson design skills, equipping them to navigate and lead such collaboration in future practice.

Our results also show challenges regarding shifting norms of interaction among colleagues. Twan, for example, perceived resistance when his team's work was labelled as the "Twan-Kim-Milan Show". Research on teacher leadership has indicated that relationships between teacher leaders and their peers are often negatively affected, because peers may resent the disrupted established norms (Oppi et al., 2023; Wenner & Campbell, 2017). When teachers take on a leadership role, colleagues may perceive a shift in authority, feeling that someone who was once their equal now has the power to influence their practice (Meyer & Slater-Brown, 2022). This tension can undermine collaboration; some studies have even suggested the need to "protect teacher leaders from their colleagues" (York-Barr & Duke, 2004, p. 273). To address this, all teachers should be involved in discussions about distributed leadership, emphasizing collaboration and shared decision-making rather than exercising authority. Our results highlight the need for further research to explore how norms of interaction among teachers can be supported to enable collective learning to achieve educational change.

During the second year of the PLC, we invited an additional teacher from each school, aiming to reinforce internal collaboration (Fitzgerald et al., 2019). While this approach showed promise in Case II and Case III,

it was inadequate in Case I. This suggests that future PLCs must work systematically with school leadership to foster collegial environments. Our comparison of the three cases shows that without strong internal teacher communities, even well-designed professional learning initiatives such as this PLC may have limited impact.

4.3. School structure

Our results show that Case II stands out in how the call for ESD implementation was translated into the school's local organizational context. Consistent with existing literature, educational change often unfolds differently than intended due to school structures (Vermeir et al., 2017). In Case II, teachers deliberately chose to implement ESD through school-based curriculum activities rather than within school subjects. This approach was enabled by the school's structural support for such activities, which provided the flexibility and autonomy needed to implement ESD. One implication of this result is that stakeholders within a school should deliberately look for where ESD fits in their existing school structure.

Reform-oriented goals such as ESD, which are not yet embedded in national curricula, are often difficult for teachers to translate into practice, due to little flexibility in the curriculum and the pedagogical practices promoted by teachers' institutions (Corres et al., 2024; Schutte et al., 2025a). In particular, the structuring of curricula around subjects has been identified as a key barrier to tackling ESD (Mulà & Tilbury, 2023). Additionally, a focus on measurable learning outcomes constrains teachers' autonomy, limiting their engagement with the open-ended nature of ESD (Tryggvason et al., 2022). Our results contribute to this body of literature, showing that teachers relied on school-based curricular activities to implement ESD, since these activities offered flexibility and greater autonomy (Chobphon, 2024). While some studies advocate a formal curriculum centred on sustainability (Miedijensky & Abramovich, 2019), our results suggest that school structure has the potential to facilitate meaningful ESD implementation, even without a sustainability-focused curriculum. However, we acknowledge that further research is needed to assess the quality of the education provided through these school-based curricular activities.

While each case is different and not comparable, our results show that Floris and Max in Case II did not encounter the same challenges as the teachers in the other cases. This difference may relate to the school's structure, which positioned teachers as curriculum designers within school-based activities. This autonomy appeared to shield Floris and Max from organizational barriers such as peer dynamics or unclear roles. Moreover, teachers' existing teaching habits influence their uptake of ESD, as those already accustomed to interdisciplinary collaboration do not experience its implementation as time-consuming (van Poeck et al., 2025). We argue that when teachers are already positioned as designers, it becomes easier for them to lead and collaboratively shape ESD implementation (Scheie et al., 2025; Stouthart et al., 2023). Moreover, principal backing is critical for teacher-led educational change (Reinius et al., 2022), as we saw in Case II when the principal embedded the integration of the SDGs into the school's vision.

Another factor contributing to implementation in Case II was how Floris and Max framed ESD. Rather than presenting it as a formal educational change, which they believed could trigger resistance, they encouraged integrating ESD into existing practices and highlighted it was already being addressed. Aligning with previous literature, our results show that teachers' perception and framing of change significantly influence their uptake of the change (Ha et al., 2008; Wilkie, 2025). Future PLCs could take note of this, supporting teachers in building on existing teaching materials and incorporating reform-oriented goals incrementally. This approach allows professional learning to operate within teachers' zones of proximal development, introducing novelty while remaining accessible.

4.4. Recognition for implementing educational change in teachers' task descriptions

Is designing lessons aligned with educational change part of teachers' regular duties? Should teachers who engage in such efforts be allocated additional time? This question emerged as one of the most significant tensions in our study. Twan raised this issue with his principal after his colleagues, eager to implement a new didactic approach, felt they were investing extra time that warranted recognition. The principal argued that lesson planning and professional development were already part of teachers' task descriptions. However, the teachers viewed designing interdisciplinary lessons as fundamentally different from routine preparation. Aligned with recent literature, we argue that when teachers first engage with reform-oriented goals, they need extra time to design effective lessons (Reinius et al., 2022). Research has shown that recognition, whether through compensation or providing time, is a key motivator for teachers leading educational change (Meyer & Slater-Brown, 2022; Muijs & Harris, 2006; Oppi et al., 2023). Treating such efforts as standard lesson planning risks demotivating teachers (Valdés Sánchez & Gutiérrez-Esteban, 2023). The school in Case II, for example, provides a development fund for teachers to update their practice. As a result, teachers at this school did not experience any struggle for recognition or support. One implication of this dilemma is the need to formally recognize teachers' work in task descriptions. This recognition could foster broader teacher participation in educational innovation. Principals should allocate time for teachers to work across disciplines, especially in the context of ESD, which involves tackling complex sustainability issues through interdisciplinary collaboration (Ariza et al., 2021).

5. Conclusion

York-Barr and Duke (2004, p.255) stated that "Teachers rightly and importantly hold a central position in the ways schools operate and in the core functions of teaching and learning". Building on this, our study explored whether and how various factors known to influence the implementation of educational change shaped ESD implementation at three schools. We found that while some conditions facilitated teachers' efforts, others hindered them. Among all of the factors, *community* emerged as the most impactful, referring to collegial relationships and school structures that allow curricular flexibility and teacher autonomy. Given the normative nature of ESD, its implementation is likely to be more successful from the bottom-up. Therefore, local contexts that encourage teacher leadership and collaborative professional development matter deeply. We conclude that organizational support and strong collegial interactions are key to enabling teachers to lead educational change, not only for ESD, but for broader school improvement. School environments that offer flexibility through school-based curricular activities appear particularly effective in both supporting innovation and easing the social challenges involved in leading change.

6. Limitations

While this study focuses on teachers' experiences, providing valuable insights into how teachers extend ESD implementation beyond their classrooms, it does not examine student outcomes. Moreover, the study does not examine the scale or depth of teachers' implementation within each school. Differences in the extent to which ESD was embedded may therefore remain underexplored. The conclusions are context-specific. They are based on the experiences of only seven teachers across three schools. Although the duration of the PLC spanned 3 academic years, a considerable timeframe, many events likely occurred that were not captured in our data.

Declaration of the use of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the first author used Copilot in order to improve language and readability. After using this tool, a native-speaker proofreader reviewed and edited the language as needed. The authors take full responsibility for the content of the published article.

CRediT authorship contribution statement

Tuba Stouthart: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Funding acquisition. **Dury Bayram:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Jan van der Veen:** Writing – review & editing, Methodology, Conceptualization.

Ethics statement

Informed consent was obtained from all participants involved in the study in accordance with the ethical guidelines from Eindhoven University of Technology. The study was approved by the Ethical Review Board (ERB) on October 3, 2022 with reference code ERB2022AP3.

Declaration of competing interests

The authors declare no conflict of interest.

Acknowledgements

This research was funded by the Dutch Research Council (NWO) under Dudoc-Béta programme with grant number 40.5.22395.002. The authors express their gratitude to the participants and take full responsibility for the text of this article.

Appendix

Table A1
Coding categories, factors, individual codes, and example excerpts

Category	Sub-category (factor)	Code	Excerpt
Characteristics of Change	Need	Authenticity	We let them [students] do small assignments on a local scale to see what kind of privilege they have, but we also have talks with refugees. We have talks with ex-convicts. So we let them experience and see different perspectives on the privilege that they have. (Max, Case II)
		Sustainability/SDGs	The sustainability part for me was the most important part, and challenge-based learning is a nice way to implement sustainability in your curriculum. (Floris, Case II)
		Skill development	I formulated it as follows; the students should learn to self-assess. Self-assess can be evaluating the learning process itself, if they want by using grades, that's open. (Twan, Case III)
	Clarity	Challenge-based learning	I lean more towards the challenge-based learning aspect because that is where the similarities between our project and challenge-based learning lie. (Twan, Case III)
		Sustainability	You need many competences yourself as a teacher to teach sustainability, that's not easy to make a subject out of it. And it might be a big risk actually because if I start a sustainability subject, I mainly will focus on the climate change aspects, but not the emotions because I'm not an emotional person [jokingly]. (Floris, Case II)
		Fidelity	They [goals of the PLC] were not clear at the start, but that's maybe the idea of this group also. So we also grew in what we expected of each other, and what our goal would be, and towards the end of the first year the main goal got sharper. (Floris, Case II)
	Complexity	Different	People [colleagues] were really interested, 'So you have a methodology, do you have some materials that you can share?' And the answer is almost always no. I don't have materials that you can just implement, it's a methodology. It's something that you have to learn. (Twan, Case III)
		Not teacher role	Well, it feels a bit like if I need to get the other teachers involved, it feels a bit like I'm a sales manager. (Bas, Case I)
	Quality/ Practicality	Brings diverse people together	It doesn't always seem like it's very important, or very useful what we do in these groups, but without the entire PLC group and without these meetings, there would be no progression. (Floris, Case II)
		Theory	Every teacher is different, but I'm not a teacher that really likes to have everything based on theory. … it's not my thing. (Bas, Case I)
		Workload/time	… there's a lot of, you know, a lot on our plates. And so sometimes, often, it's easier to just say, okay, we'll just do this from the book … (Twan, Case III)
Local Characteristics	Region*	Eindhoven	We have closer connections to the companies in the region. And there are a lot of projects being run that have started with this Brainport concept [the innovation-focused Eindhoven region]. (Floris, Case II)
	Community	Board	Well, I think we're fortunate enough to have the support of our principal, even the new one. I think the entire school board is enthusiastic about the idea. (Twan, Case III)
		School	The road to the inspiration session was already little bit tricky because we had a spot that was reserved for us in the afternoon. … and the management kept on changing the conditions. … The result was that we had only few teachers that were able to attend because it was also parallel to other sessions. The communication was really at the last minute. (Twan, Case III)
		Finance	They also look at it from a financial aspect. … the first year when I started my project … I was able to work for 1 1/2 days per week on my project, and so that's substantial. And this has been scaled down and scaled down … (Twan, Case III)
		Colleagues	Teachers do not want to do anything extra. If it's not in the curriculum, teachers do not want to do it. (Bas, Case I)
		Students	Because we feel that it tackles one of the problems that we see in high school that students forget everything they learn about that subject the moment they leave the classroom. It is like they empty their mind, enter the next classroom, and then hear something maybe that is said 2 h ago in Maths but then in Economics, 'No, we have never learned how to do'. (Kim, Case III)
	Principal	Involvement from the beginning	I think that maybe getting the director from the schools, getting them more involved, sooner as well. (Bas, Case I)

(*continued on next page*)

Table A1 (*continued*)

Category	Sub-category (factor)	Code	Excerpt
		Facilitating the implementation	There needs to be conversations with the other teachers, stimulate them, provide them with hours to create something like this. I get 80 h … but just the fact that I have hours to create something, just stimulates me to do it. (Bas, Case I)
	Teacher	Personality	What I need in order to be creative and chaotic is a really structured environment. … I love this group of people. But this is so not structured that what it does to me, I become anxious, I become insecure. (Twan, Case III)
		Skills/capacity	If there's one thing that I would have liked to see in the first year of PLC or in this year, it is maybe someone coming there, talking about how to change. We have quite a managing role also and I'm not a change maker, or I haven't had a course on how to implement something. (Floris, Case II)
External Factors	Curriculum*	Assessment	If you think about the national exams, it is clearly defined what the students have to do … whereas in challenge-based learning, it is skills driven. … Checking content is easier. Skills, it is team based. How do you assess that? (Twan, Case III)
		Little sustainability	We're [he and his students] talking a lot about energy, but there's not the connection with sustainability … well, I'm just following the book, my curriculum. If I could leave the book … then probably I would get sustainability more involved. (Bas, Case I)
		Autonomy	It would be lovely if there would just be more room … that you would have a curriculum, let's say, for 70% of the time, and 30% the government says, 'Well, the teachers, they have a good education, we trust them … let them do whatever they think that is good for their students'. (Bas, Case I)

Note: We use the term *region* instead of *district* as identified in the original framework, and *curriculum* instead of *government and other agencies*. These substitutions are indicated by an asterisk (*).

Data availability

Data will be made available on request.

References

Ariza, M. R., Christodoulou, A., van Harskamp, M., Knippels, M.-C. P. J., Kyza, E. A., Levinson, R., & Agesilaou, A. (2021). Socio-scientific inquiry-based learning as a means toward environmental citizenship. *Sustainability, 13*. https://doi.org/10.3390/su132011509

Arntzen, M., Scheie, E., & Haug, B. (2025). Interdisciplinary ESE: Barriers to implementation and practical ways to overcome them. *Environmental Education Research*. https://doi.org/10.1080/13504622.2025.2594637

Bahçekapili, T. (2018). *An investigation of 1:1 technology initiative through the lens of Fullan's educational change model: A three-year study*. Middle East Technical University, Middle East Technical University. Doctoral dissertation https://etd.lib.metu.edu.tr/upload/12622862/index.pdf.

Balgopal, M. M. (2020). STEM teacher agency: A case study of initiating and implementing curricular reform. *Science Education, 104*(4), 762–785. https://doi.org/10.1002/sce.21578

Berglund, T., Gericke, N., Forssten Seiser, A., Mogren, A., & Olsson, D. (2025). The role of ESD facilitators in bringing about change in schools. *Environmental Education Research, 31*(7), 1436–1460. https://doi.org/10.1080/13504622.2025.2486367

Binkhorst, F., Poortman, C., McKenney, S., & van Joolingen, W. (2022). Leadership in teacher design teams for professional development: Research synthesis and applications for coaches. *Irish Educational Studies, 43*(4), 751–771. https://doi.org/10.1080/03323315.2022.2148264

Boeije, H. (2009). *Analysis in qualitative research (Reprint)*. SAGE.

Bosevska, J., & Kriewaldt, J. (2020). Fostering a whole-school approach to sustainability: Learning from one school's journey towards sustainable education. *International Research in Geographical & Environmental Education, 29*(1), 55–73. https://doi.org/10.1080/10382046.2019.1661127

Burnes, B. (2004). Kurt Lewin and the planned approach to change: A re-appraisal. *Journal of Management Studies, 41*(6), 977–1002. https://doi.org/10.1111/j.1467-6486.2004.00463.x

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

Cheng, A. Y. N., & Szeto, E. (2016). Teacher leadership development and principal facilitation: Novice teachers' perspectives. *Teaching and Teacher Education, 58*, 140–148. https://doi.org/10.1016/j.tate.2016.05.003

Chobphon, P. (2024). Global citizenship education in a politically polarised country: Thai teachers' perspectives. *Teaching and Teacher Education, 138*, Article 104428. https://doi.org/10.1016/j.tate.2023.104428

Corres, A., Ruiz-Mallén, I., & Rieckmann, M. (2024). Educators' competences, motivations and teaching challenges faced in education for sustainable development: What are the interlinkages? *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2302408

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE.

Daumiller, M., Keller, M. V., & Dresel, M. (2025). Exploring the role of teacher self-efficacy and personal environmental practices in integrating sustainability into teaching: A network analysis of German teachers. *Sustainability, 17*(16). https://doi.org/10.3390/su17167533

Ellingson, C. L. (2018). *Teachers as curriculum designers: Understanding STEM pedagogical design capacity [doctoral dissertation*. University of Minnesota. https://hdl.handle.net/11299/199085.

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

Fitzgerald, M., Danaia, L., & McKinnon, D. H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: Perceptions of positively inclined early adopters. *Research in Science Education, 49*(2), 543–566. https://doi.org/10.1007/s11165-017-9623-5

Ford, T. G., & Youngs, P. A. (2018). Creating organizational structures to facilitate collegial interaction among teachers: Evidence from a high-performing urban Midwestern US district. *Educational Management Administration & Leadership, 46*(3), 424–440. https://doi.org/10.1177/1741143216682501

Forssten Seiser, A., Mogren, A., Gericke, N., Berglund, T., & Olsson, D. (2023). Developing school leading guidelines facilitating a whole school approach to education for sustainable development. *Environmental Education Research, 29*(5), 783–805. https://doi.org/10.1080/13504622.2022.2151980

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

Gericke, N., & Torbjörnsson, T. (2022). Identifying capital for school improvement: Recommendations for a whole school approach to ESD implementation. *Environmental Education Research, 2022*(6), 803–825. https://doi.org/10.1080/13504622.2022.2045256

Ghamrawi, N., Shal, T., Ghamrawi, N. A. R., Abu-Tineh, A., & Alshaboul, Y. (2025). Unleashing the potential of teacher leadership for ESD. In *Frontiers in education* (Vol. 10). Frontiers Media SA. https://doi.org/10.3389/feduc.2025.1614623

Gordon, P. A. (2024). *Implementing inquiry: A case study of secondary science teachers' perceptions of curriculum change [doctoral dissertation*. St. John's University, St. John's University. https://scholar.stjohns.edu/theses_dissertations/701.

Ha, A. S., Wong, A. C., Sum, R. K., & Chan, D. W. (2008). Understanding teachers' will and capacity to accomplish physical education curriculum reform: The implications for teacher development. *Sport, Education and Society, 13*(1), 77–95. https://doi.org/10.1080/13573320701780746

Handelzalts, A., Nieveen, N., & Van Den Akker, J. (2019). Teacher design teams for school-wide curriculum development: Reflections on an early study. In J. Pieters, J. Voogt, & N. Pareja Roblin (Eds.), *Collaborative curriculum design for sustainable innovation and teacher learning* (pp. 55–82). Springer International Publishing. https://doi.org/10.1007/978-3-030-20062-6_4.

Harris, A., & Jones, M. (2019). Teacher leadership and educational change. *School Leadership & Management, 39*(2), 123–126. https://doi.org/10.1080/13632434.2019.1574964

Holst, J., Grund, J., & Brock, A. (2024). Whole Institution approach: Measurable and highly effective in empowering learners and educators for sustainability. *Sustainability Science, 19*(4), 1359–1376. https://doi.org/10.1007/s11625-024-01506-5

Huizinga, T., Handelzalts, A., Nieveen, N., & Voogt, J. M. (2014). Teacher involvement in curriculum design: Need for support to enhance teachers' design expertise. *Journal of Curriculum Studies, 46*(1), 33–57. https://doi.org/10.1080/00220272.2013.834077

Isac, M. M., Sass, W., Pauw, J. B. De, De Maeyer, S., Schelfhout, W., Van Petegem, P., & Claes, E. (2022). Differences in teachers' professional action competence in education for sustainable development: The importance of teacher co-learning. *Sustainability, 14*(2). https://doi.org/10.3390/su14020767

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

Korhonen, T., Salo, L., Laakso, N., Seitamaa, A., Sormunen, K., Kukkonen, M., & Forsström, H. (2023). Finnish teachers as adopters of educational innovation: Perceptions of programming as a new part of the curriculum. *Computer Science Education, 33*(1), 94–116. https://doi.org/10.1080/08993408.2022.2095595

Lai, E., & Cheung, D. (2015). Enacting teacher leadership:the role of teachers in bringing about change. *Educational Management Administration & Leadership, 43*(5), 673–692. https://doi.org/10.1177/1741143214535742

Lewin, K. (1947). Frontiers in group dynamics: Concept, method and reality in social science; social equilibria and social change. *Human Relations, 1*(1), 5–41.

Meyer, F., & Slater-Brown, K. (2022). Educational change doesn't come easy: Lead teachers' work as change agents. *Mathematics Education Research Journal, 34*(1), 139–163. https://doi.org/10.1007/s13394-020-00333-y

Miedijensky, S., & Abramovich, A. (2019). Implementation of "education for sustainability" in three elementary schools-what can we learn about a change process? *Eurasia Journal of Mathematics, Science and Technology Education, 15*(10). https://doi.org/10.29333/ejmste/109145

Miles, M., & Huberman, M. (1994). *Qualitative data analysis: An expanded sourcebook*. SAGE.

Mogren, A., & Gericke, N. (2017). ESD implementation at the school organisation level, part 1–investigating the quality criteria guiding school leaders' work at recognized ESD schools. *Environmental Education Research, 23*(7), 972–992. https://doi.org/10.1080/13504622.2016.1226265

Mogren, A., & Gericke, N. (2019). School leaders' experiences of implementing education for sustainable development-anchoring the transformative perspective. *Sustainability, 11*(12). https://doi.org/10.3390/su11123343

Mogren, A., Gericke, N., & Scherp, H.Å. (2019). Whole school approaches to education for sustainable development: A model that links to school improvement. *Environmental Education Research, 25*(4), 508–531. https://doi.org/10.1080/13504622.2018.1455074

Muijs, D., & Harris, A. (2006). Teacher led school improvement: Teacher leadership in the UK. *Teaching and Teacher Education, 22*(8), 961–972. https://doi.org/10.1016/j.tate.2006.04.010

Mulà, I., & Tilbury, D. (2023). Teacher education for sustainability: Current practice and outstanding challenges. *Advances in Research in Mathematics Education*, (23), 5–18. https://doi.org/10.35763/aiem23.5414

Nieveen, N., & Kuiper, W. (2012). Balancing curriculum freedom and regulation in the Netherlands. *European Educational Research Journal, 11*(3), 357–368. https://doi.org/10.2304/eerj.2012.11.3.357

Onderwijsraad. (2017). Een ander perspectief op professionele ruimte in het onderwijs [Another perspective on professional space in education] https://www.onderwijsraad.nl/site/binaries/site-content/collections/documents/2016/09/27/een-ander-perspectief-op-professionele-ruimte-in-het-onderwijs/Een-ander-perspectief-op-professionele-ruimte-in-het-onderwijs.pdf.

Oppi, P., Eisenschmidt, E., & Stingu, M. (2023). Seeking sustainable ways for school development: Teachers' and principals' views regarding teacher leadership. *International Journal of Leadership in Education, 26*(4), 581–603. https://doi.org/10.1080/13603124.2020.1849809

Patton, M. Q. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (4th ed.). SAGE.

Priestley, M., Edwards, R., Priestley, A., & Miller, K. (2012). Teacher agency in curriculum making: Agents of change and spaces for manoeuvre. *Curriculum Inquiry, 42*(2), 191–214. https://doi.org/10.1111/j.1467-873X.2012.00588.x

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

Reinius, H., Kaukinen, I., Korhonen, T., Juuti, K., & Hakkarainen, K. (2022). Teachers as transformative agents in changing school culture. *Teaching and Teacher Education, 120*, Article 103888. https://doi.org/10.1016/j.tate.2022.103888

Sass, W., De Maeyer, S., Boeve-De Pauw, J., & Petegem, P. Van (2024). Effectiveness of education for sustainability: The importance of an action-oriented approach. *Environmental Education Research, 30*(4), 479–498. https://doi.org/10.1080/13504622.2023.2229543

Scheie, E., Arntzen, M., & Haug, B. S. (2025). Teachers' implementation of self-designed interdisciplinary curriculum units in education for sustainable development. *Research in Science Education, 55*(4), 793–815. https://doi.org/10.1007/s11165-025-10279-5

Scherak, L., & Rieckmann, M. (2022). Development and assessment of ESD competences: Staff training at the university of Vechta. In P. Vare, N. Lausselet, & M. Rieckmann (Eds.), *Competences in education for sustainable development* (pp. 121–128). Springer. https://doi.org/10.1007/978-3-030-91055-6_15.

Schutte, B. G., Bayram, D., Vennix, J., & van der Veen, J. (2025a). Exploring the implementation of challenge-based learning for sustainability education in Dutch secondary education: Teachers' experiences. *Environmental Education Research, 31*(6), 1166–1192. https://doi.org/10.1080/13504622.2025.2458723

Schutte, B. G., Bayram, D., Vennix, J., & van der Veen, J. (2025b). *Navigating interdisciplinary barriers: Implementing challenge-based learning for sustainable development in secondary education*. Department of Applied Physics and Science Education, Eindhoven University of Technology [Unpublished Manuscript].

Sinha, S., & Hanuscin, D. L. (2017). Development of teacher leadership identity: A multiple case study. *Teaching and Teacher Education, 63*, 356–371. https://doi.org/10.1016/j.tate.2017.01.004

SLO. (2022). Verdeling van ontwerpruimte voor ontwikkeling van kerndoelen. www.slo.nl.

Spillane, J. P., Halverson, R., & Diamond, J. B. (2001). Investigating school leadership practice: A distributed perspective. *Educational Researcher, 30*(3), 23–28. https://doi.org/10.3102/0013189X030003023

Stouthart, T., Bayram, D., & Van Der Veen, J. (2023). Capturing pedagogical design capacity of STEM teacher candidates: Education for sustainable development through socioscientific issues. *Sustainability, 15*(14), Article 11055. https://doi.org/10.3390/su151411055

Taskin-Ekici, F., Kocagul-Saglam, M., & Ekici, E. (2025). Teachers' profiles for education for sustainable development: Implications for professional development. *Environmental Education Research*. https://doi.org/10.1080/13504622.2025.2605221

Teherani, A., Martimianakis, T., Stenfors-Hayes, T., Wadhwa, A., & Varpio, L. (2015). Choosing a qualitative research approach. *Journal of Graduate Medical Education, 7*(4), 669–670. https://doi.org/10.4300/JGME-D-15-00414.1

Tryggvason, Á., Sund, L., & Öhman, J. (2022). Schooling and ESE: Revisiting Stevenson's gap from a pragmatist perspective. *Environmental Education Research, 28*(8), 1237–1250. https://doi.org/10.1080/13504622.2022.2075326

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

UNESCO. (2015). Transforming our world: The 2030 Agenda for sustainable development. https://www.refworld.org/docid/57b6e3e44.html.

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

Valdés Sánchez, V., & Gutiérrez-Esteban, P. (2023). Challenges and enablers in the advancement of educational innovation. The forces at work in the transformation of education. *Teaching and Teacher Education, 135*, Article 104359. https://doi.org/10.1016/j.tate.2023.104359

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

van Poeck, K., Lidar, M., Lundqvist, E., & Östman, L. (2025). When teaching habits meet educational innovation: Problematic situations in the implementation of sustainability education through 'open schooling.'. *Environmental Education Research, 31*(3), 605–626. https://doi.org/10.1080/13504622.2024.2405889

Verhelst, D., Mogren, A., Boeve-de Pauw, J., & Van Petegem, P. (2024). Getting to a whole school approach: Lessons from school effectiveness and school improvement in ESD research. In A. E. Wals, B. Bjønness, A. Sinnes, & I. Eikeland (Eds.), *Whole school approaches to sustainability: Part F3104* (pp. 71–86). Springer. https://doi.org/10.1007/978-3-031-56172-6_5.

Verhelst, D., Vanhoof, J., & Van Petegem, P. (2021). School effectiveness for education for sustainable development (ESD): What characterizes an ESD-effective school organization? *Educational Management Administration & Leadership, 51*(2). https://doi.org/10.1177/1741143220985196

Vermeir, K., Kelchtermans, G., & März, V. (2017). Implementing artifacts: An interactive frame analysis of innovative educational practices. *Teaching and Teacher Education, 63*, 116–125. https://doi.org/10.1016/J.TATE.2016.12.006

Wals, A. (2006). The end of ESD. *The beginning of transformative learning. Emphasizing the "E" in ESD*. https://www.researchgate.net/publication/40108700.

Wals, A., Bjønness, B., Sinnes, A., & Eikeland, I. (Eds.). (2024). *Whole school approaches to sustainability*. Springer. https://doi.org/10.1007/978-3-031-56172-6.

Wals, A., & Mathie, R. (2022). Whole school responses to climate urgency and related sustainability challenges. In *Encyclopedia of educational innovation* (pp. 1–8). Springer. https://doi.org/10.1007/978-981-13-2262-4_263-2.

Wenner, J. A., & Campbell, T. (2017). The theoretical and empirical basis of teacher leadership: A review of the literature. *Review of Educational Research, 87*(1), 134–171. https://doi.org/10.3102/0034654316653478

Wilkie, K. J. (2025). Maintaining momentum: Teacher-leaders' identity narratives about transforming school mathematics practice. *Teaching and Teacher Education, 168*. https://doi.org/10.1016/j.tate.2025.105234

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE.

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research, 74*(3), 255–316.

Zeidler, D. L. (2014). Socioscientific issues as a curriculum emphasis: Theory, research, and practice. In N. G. Lederman, & S. K. Abell (Eds.), *Handbook of research in science education* (Vol. II, pp. 697–726). Routledge.

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