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Science Education for Collective Agency in the Climate Crisis: A Social Identity Approach

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Abstract
In this era of climate crisis, science education must educate climate-literate citizens capable of steering the required transformation. According to the Vision III of scientific literacy, students need to be equipped with the civic ability to translate scientific knowledge into a values-driven transformation. However, if the goal of the Paris Climate Agreement is taken seriously, not only individual but also (and even more so) collective agency is of great importance to achieve rapid decarbonisation. Currently, science education focuses on promoting personal climate action of individual actors, neglecting the collective dimension and the way group processes shape the appraisal of and response to the climate crisis. To explore how science education can foster collective agency, we utilise the Social Identity Model of Pro-environmental Action (SIMPEA) from the field of environmental psychology. The SIMPEA describes how the three basic social identity processes of ingroup identification, collective efficacy beliefs and ingroup norms and goals influence the appraisal of and response towards a crisis. Based on the SIMPEA, we identify principles of education for transformation (PET) with the potential to enable group identification by individuals, which in turn shape appraisal and response, influencing whether an individual takes action in both the private and public spheres. This conceptual paper discusses five PETs and explores how and which social identity processes they can trigger. The PETs demonstrate that science education has a high potential to facilitate collective agency in the context of climate change. Furthermore, we synthesise key elements of social identity formation in science education, such as the usage of speculative projections into the future.

Keywords Climate change · Science education · Collective agency · Social identity · Education for transformation

Introduction

Today, science education (SE) takes place in a time of escalating socio-ecological crises that require urgent action, particularly in response to climate change (CC) (IPCC, 2023). Public and political discourse has largely focused on individual behavioural

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change, such as reducing personal carbon footprints or practising green consumerism (Maniates, 2001), placing the burden of decarbonisation disproportionately on individuals (Akenji, 2014). This framing is echoed in SE, which has so far prioritised personal climate actions of individuals (Kranz, 2024; Kranz et al., 2022). Yet, such approaches risk not only 'privatising' the climate crisis but also neglect the social contexts that shape how people perceive and respond to collective threats (Fritsche et al., 2018).

Against this backdrop, educational policy frameworks increasingly call for a broader understanding of agency, viewed broadly as the capacity for social engagement (Otto et al., 2020). For example, the PISA Science Framework 2025 (White et al., 2023) emphasises responsible citizenship as key to enabling learners to make informed decisions and actively shape their lives and the broader world. In a similar vein, the evolving concept of scientific literacy from Vision I (focus on scientific content, products and processes of science), to Vision II (linking science to everyday and social contexts), to Vision III – aims at socio-political engagement by focusing on the civic ability to translate scientific facts and principles into a values-driven transformation of society. Vision III repositions SE not merely as a vehicle for transmitting knowledge or individual action taking, but as a transformative practice that fosters ethically grounded, civic engagement (Hodson, 2020; Sjöström, 2024; Sjöström & Eilks, 2018). Such a critical-reflexive approach to SE connects to the idea that collective agency is essential for positive change.

Despite increasing recognition of the importance of agency, practical guidance on how to foster such agency in SE remains limited. While several psychological models have been influential in explaining pro-environmental behaviour also within educational contexts, such as the Theory of Planned Behaviour (Ajzen, 1991), Value-Belief-Norm Theory (Stern et al., 1999), or Self-Efficacy Theory (Bandura, 1997), these conceptualizations are grounded in a predominantly individualistic view of agency. They frame behavioural change primarily as a function of internal variables such as personal attitudes, moral beliefs, or self-perceived efficacy. While useful, they offer only partial insight into how individuals engage with collective crises like CC. In contrast, environmental psychology highlights that climate-related action is not only—and perhaps not primarily—a matter of personal conviction, but deeply shaped by how individuals see themselves as part of a social group (Fritsche et al., 2018; Masson & Fritsche, 2021; Reese et al., 2020). Social identity processes, such as ingroup identification, shared norms and goals, and perceived collective efficacy play a key role in how people appraise CC and decide to act (Fritsche et al., 2018). These mechanisms explain why people are more likely to engage in climate-relevant behaviours when they perceive that their social group, whether peers, school or broader humanity, is also engaged and capable of effecting change. To support this collective perspective on agency in SE, we draw in this conceptual paper (Jaakkola, 2020), on the Social Identity Model of Pro-Environmental Action (SIMPEA; Fritsche et al., 2018; see Fig. 1), which explains pro-environmental action through group-based processes. Our rationale for selecting SIMPEA includes the following considerations:

1. SIMPEA builds on a strong foundation in social identity theory (Tajfel & Turner, 1979) and integrates various predictors of pro-environmental behaviour, many of which have been empirically tested (for an overview, see Masson & Fritsche, 2021). Meanwhile, we do acknowledge that SIMPEA does not provide an exhaustive model for collective identity formation, as for example it does not pay explicit attention to surrounding power structures and hegemonic social identities that may influence identity formation.

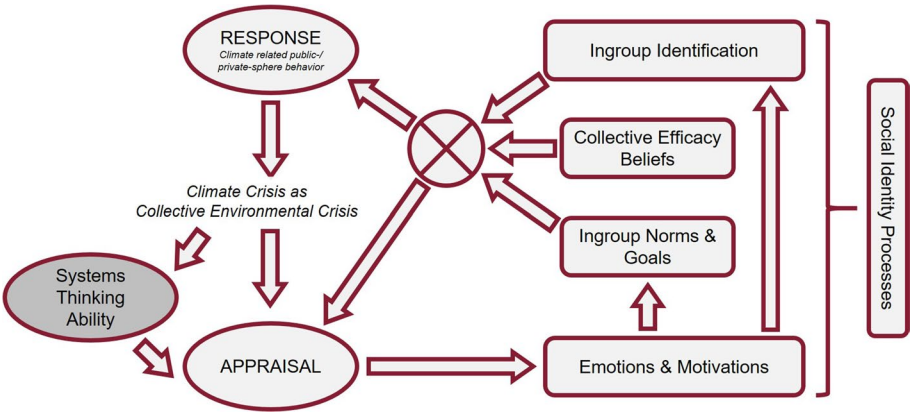

Fig. 1 This figure is a reelaboration of the SIMPEA model from Fritsche et al. 2018 and Reese et al. (2020)

2. In contrast to earlier social identity models of collective action (e.g., van Zomeren et al., 2008), which have tended to focus on motivation within conflict-based, politicised intergroup contexts, SIMPEA extends the scope to non-conflictual, non-activist settings, and to any self-relevant group, such as schools or local communities, making it highly suitable for application in SE. The model suggests that action does not require an antagonistic group dynamic but can also be driven by the shared perception of environmental crises as collective threats (Masson & Fritsche, 2021).
3. We argue that individuals' appraisal of the climate crisis depends not only on group processes but also on their scientific knowledge and systems thinking ability. Systems thinking, which integrates scientific knowledge with creative and analytical competencies, enables students to explore and evaluate effective courses of action for regenerating and sustaining Earth's systems, an essential learning outcome in SE (Young et al., 2006). This perspective aligns with a recent qualitative extension of SIMPEA, which highlights the crucial role of systems thinking in pro-environmental action (Reese et al., 2020). More broadly, SIMPEA resonates with core elements of the PISA Science Framework 2025 for agency in the Anthropocene (White et al., 2023), like systems thinking, or building efficacy and hope.
4. The model allows for a nuanced understanding of pro-environmental behaviour by addressing not only private-sphere behaviour (e.g., climate friendly consumer choices) but also public-sphere engagement (e.g., civic participation), thereby supporting a more comprehensive and collective understanding of agency (Fritsche et al., 2018). Moreover, SIMPEA integrates not only deliberate appraisals but also affective and automatic responses to environmental threats (Fritsche et al., 2018; Masson & Fritsche, 2021), offering a more comprehensive account of how individuals come to act as members of a group.

While psychologists have highlighted that SIMPEA can offer interesting new perspectives for teaching interventions (Fritsche et al., 2018), it has not yet been systematically applied in SE. This paper addresses that gap by exploring how SE can contribute to the development of collective agency in response to the climate crisis. To do so, we first outline the theoretical rationale and key components of SIMPEA. Next, rather than using SIMPEA solely as a theoretical lens, we apply SIMPEA as a conceptual tool to identify

and interpret five pedagogical configurations, *Principles of Education for Transformation* (PET). Each PET illustrates key social identity processes and is exemplified through project-based educational approaches. We conclude by synthesising shared features of these PETs and discuss implications for fostering collective agency in SE.

The Social Identity Model of Pro-Environmental Action (SIMPEA)

The SIMPEA stems from the field of environmental psychology and highlights the collective dimension of pro-environmental action (Fritsche et al., 2018). Social identity is the part of the self that is derived from knowledge of and emotional attachment to groups (Tajfel & Turner, 1979). It describes the state where people think and act in line with collectives; thus, they are in a state of "we" thinking, instead of "I" thinking (Fritsche et al., 2018; Masson & Fritsche, 2021). The self-categorisation to a social group influences the perception and reaction of its members to a crisis through shared norms, goals, and beliefs (Turner et al., 1987), which can drive social change but also resistance to it (Rosenmann et al., 2016).

The framework systematically outlines three basic social identity processes (Fritsche et al., 2018) and explains how they shape people's appraisal of, and response to, collective environmental crises. The response and appraisal in turn, shape emotions and motivations that affect the other social identity processes again. The social identity processes interact, shaping responses to the collective crisis, influencing whether an individual takes action in both the private and public spheres (see Fig. 1). Next, we will describe the elements of the model and their relevance in the climate crisis in more detail.

Ingroup Identification According to the SIMPEA, ingroup identification can occur on different levels of social environments (i.e., class, school, Fridays for Future or even humanity as a whole) and influences the perception of the crisis (e.g., CC being a collective rather than a personal risk). Social identification as a member of a group can affect behavioural responses, specifically climate friendly behaviour in our case.

Collective Efficacy This is the belief that *our* actions can make a measurable difference (e.g., we can introduce plant-based options to the school cafeteria menu).

Norms and Goals These describe shared rules and standards that shape the perception of what members of the group do or should not do (i.e., it is important to speak about the climate crisis with friends and family).

Emotions and Motivations These processes are described as emerging from the appraisal of the environmental crisis and mediating the effect of other social identity variables, and relate to pro-environmental actions (i.e., guilt about past negative climate behaviour affects one's willingness to engage in reparation actions).

Response The social identity processes influence whether people choose private-sphere actions with a direct but small impact (e.g. buying second-hand clothes) or public-sphere actions of environmental citizenship with an indirect yet large impact (e.g., lobbying for climate policy) (Stern, 2000).

Appraisal Following the SIMPEA, responses to a collective crisis guide the appraisal of the crisis itself (i.e., the climate crisis is seen as a risk to humanity's livelihood) and people's emotions and motivations.

However, we argue that the appraisal of the climate crisis may depend not only on the social processes described before, but also on people's scientific knowledge and their systems thinking ability (i.e., the ability to understand interrelated components and feedback loops within environmental, political, social, and economic systems). Accordingly, a recent extended interpretation of the SIMPEA incorporated systems thinking as an additional predictor in the appraisal of a collective crisis. (Reese et al., 2020).

Overall, the SIMPEA provides a suitable framework to identify educational approaches that hold the potential to build on these psychological pathways, catalysing collective agency and thus the transformative potential of SE for climate action.

From the SIMPEA to Educational Practice: Identifying Principles of Education for Transformation (PETs)

To demonstrate the potential of SE in fostering collective agency in response to the climate crisis, we analyse five educational approaches that can engage core social identity processes articulated in the SIMPEA and shape students' appraisal of and response to the climate crisis (Fritsche et al., 2018). Thereby, we aim to identify what we term *Principles of Education for Transformation* (PETs)**,** pedagogical configurations that not only aim at change, but work explicitly through the social identity processes required to make such change possible. The PETs were identified through iterative purposive sampling, understood as the deliberate selection of information-rich cases that can illuminate central theoretical constructs in depth (Patton, 2002). Our aim was not to compile an exhaustive catalogue of climate-related SE practices, but to select a conceptually rich and diverse set of cases that would allow us to identify social identity processes and explore how SIMPEA can function as an interpretive and generative lens within SE. Cases were identified through previous research, professional networks, and engagement with the relevant literature. We applied criterion-based purposive sampling (Patton, 2002), guided by four key criteria: a) internal coherence within the case (ensuring relations between SE, CC, and social identity are evident and consistent throughout each case); b) comparability among the cases (using the SIMPEA consistently across different cases to use the model as a lens); c) efficacy of the cases (highlighting the evidence of the transformative potential); d) compactness of the case (reducing redundancy and focusing on the most pertinent examples). To enhance the credibility and trustworthiness of the process, we employed analyst triangulation (Denzin & Lincoln, 2005; Patton, 2002) through collaborative analysis and structured dialogue among an interdisciplinary team of researchers in SE, CC education, environmental and sustainability studies.

Crucially, we do not claim that the PETs were designed using the SIMPEA. Rather, we offer a retrospective conceptual synthesis that shows how their pedagogical structures engage SIMPEA's core identity mechanisms in contextually specific ways. This illustrates SIMPEA's value both as an interpretive tool and as guidance for designing future learning environments aimed at building collective agency. Together, the PETs function as strategic and illustrative examples (Flyvbjerg, 2011) showing how learners' personal identities, values, and emotions can be re-situated within collective processes of meaning making and

belonging. In doing so, they align with the ambitions of Vision III of scientific literacy (Hodson, 2020; Sjöström & Eilks, 2018), which redefines the purpose of SE as enabling ethically grounded, politically engaged, and socially transformative SE.

PET 1: Global Citizenship Education

Global Citizenship Education (GCE) builds upon the concept of a global collective identity, aiming at civic learning that provides learners with the knowledge, skills, and attitudes to actively engage with the challenges and opportunities in a fast-changing and interdependent world (OXFAM, 2015; UNESCO, 2014). The UN's "Roadmap 2030" (UNESCO, 2020) underscores the significance of global citizenship in achieving the Sustainable Development Goals and states that "[Education for Sustainable Development] in action is citizenship in action". Despite a shift in SE towards civic engagement, citizenship education is not mainstream, although official documents emphasise the importance of engaging with science-related issues, like CC and science as a reflective citizen as a key educational outcome (e.g., NRC, 2012; UNESCO, 2015). As GCE is based on the formation of a shared global identity, the concept addresses the core element of the SIMPEA (Fritsche et al., 2018): the perception of an environmental crisis through the lens of one's social identity.

Due to easy and unlimited access to the world, it is possible for individuals to self-categorise with the whole of humanity, which represents a superordinate identity, as opposed to identifying solely with one's family, school or nation (Fritsche et al., 2018). Identification as a global citizen represents a social self that is based on identification with, and concern for all humanity (McFarland et al., 2019). Reysen and Katzarska-Miller (2013) found that global citizenship identification predicts sustainable attitudes and behaviours, including empathy, valuing diversity, social justice, environmental sustainability, intergroup helping and a sense of responsibility for environment-friendly action. As two antecedents of this identification, they identified global awareness and a supportive normative environment. Research also shows that global identity positively relates to climate policy support (Loy & Reese, 2019), collective climate-friendly intentions (Römpke et al., 2019) and pro-environmental behaviour (for an overview see McFarland et al., 2019).

One approach which is suggested as effective not only in meeting sustainable goals (Holst et al., 2024; UNESCO, 2020) but also as global identification building (McFarland et al., 2019), is the whole-school approach to global citizenship. In this context, global citizenship is systemically embedded in all areas of school life, involving many actors within the school setting and generally highlighting the connections and embeddedness of the school within the world. Aligned with the GCE framework (OXFAM, 2015), this approach involves: 1) integrating global citizenship into the school's vision, ethos, and development plan, with active learner participation in decision-making, 2) adapting the curriculum to include global citizenship activities, topics, and methods in an interdisciplinary manner, and 3) enabling participation processes for learners that promote global learning. It also entails 4) developing and training school staff in GCE and 5) enhancing internationalisation, for example by fostering domestic and international student interactions. Finally, it entails 6) building community engagement, for example by fostering partnerships with the local community. Some whole-school approaches explicitly integrate science perspectives on CC, focusing on achieving climate neutrality through coordinated collective student action. One such example is the "Schools for Earth" project in Germany (Weigel et al., 2023), with more than 120 schools currently enrolled. Here the focus is

on questionnaire-based climate checks, in which students identify data-driven "climate hotspots" at their own school. Following the completion of a sector-specific CO_2 assessment with a CO_2 school calculator, concrete climate mitigation measures are collectively developed. A qualitative evaluation of the approach (Werg et al., 2023) revealed that the approach contributed to a wide range of concrete measures for climate mitigation and sustainability at participants schools (e.g., energy-efficient renovation of the school, use of renewable energies, environment-friendly behaviour of the school community, waste avoidance). Respondents who were collectively involved in the whole-school approach had high overall approval ratings regarding the impact of the approach on knowledge, self-efficacy and motivation to act. In terms of the SIMPEA, these public-sphere actions might tap directly into the response to the climate crisis by uniting individuals in a collective effort to reduce the environmental impact of their schools. Furthermore, experiences of structural change towards greater sustainability in schools through participatory processes means responding together to the pillars of CC. Actually making a difference with the school as a collective might contribute to collective efficacy and motivation, which in turn can elicit social identification. Perhaps such action taking in the collective not only promotes group identification with one's own school, but when embedded in GCE, as described above, it holds opportunities to identify also with the social group of humanity. Making connections between global and local levels can reveal the interconnectedness of the origins, impacts and solutions of the climate crisis. This might encourage systems thinking and can shape how people view the crisis, fostering social identity processes itself. Additionally, a joint conceptualisation of a school vision and curriculum might contribute to a shared understanding of norms and goals.

To summarise, GCE holds the potential to activate mainly two-core social identity processes central to SIMPEA: ingroup identification, by fostering identification with humanity as a global collective and collective efficacy, by enabling learners to experience their shared capacity to address global challenges. GCE situates climate action within a broader civic and ethical commitment, helping students see themselves as part of a transnational "we" and aiming to reinforce the belief that coordinated group efforts can lead to meaningful change. In SE, GCE encourages learners to relate scientific knowledge to global issues, and to act in solidarity across cultural and geographic boundaries. Incorporating GCE into SE, for example through a whole-school approach, thus appears to be a fruitful PET by including public-sphere action as part of the actual learning experience itself.

PET 2: Future-Oriented Science Education

Future-Oriented SE (FOSE) has been emerging recently in the field of research on SE. We argue, on the basis of the SIMPEA, that SE activities addressing students' futures thinking can be powerful in fostering not only individual but also collective identities and agency.

The FOSE approach connects to sustainability education (Laherto et al., 2023) and the Vision III of SE (Sjöström, 2024). It aims to contribute to students' transformative agency and transgenerational thinking by drawing on the concepts and methods developed in the field of Futures Studies (e.g., Börjeson et al., 2006) and Futures Education. Theoretically, the approach is grounded in the temporal notions of agency, and specifically the projective dimension of agency that intertwines with how one perceives the future (Laherto & Rasa, 2022). The FOSE approach has been developed and implemented in five countries within two EU-funded projects, "I SEE" (e.g., Levrini et al., 2021) and "FEDORA" (e.g., Hyyppä et al., 2024).

The FOSE modules thus far have been targeted at upper secondary school students and have each focused on a societal theme related to science and technology. One of the modules was directly on CC (Levrini et al., 2021), but also the others have touched on global issues connected to CC with themes such as carbon sequestration and sustainable urban planning. The activities in the modules are described in detail elsewhere (Hyyppä et al., 2024; Levrini et al., 2021) – here we argue why the approach is well-fitted for fostering systems thinking ability (Reese et al., 2020) and promoting collective agency, and focus on the aspects that are most relevant in that regard.

In each FOSE module, after familiarising themselves with the scientific theme, the students work in small groups (typically 3–5 persons) throughout the module. First, they are asked to choose a personally relevant and interesting socio-scientific sustainability problem they wish to address. The groups are encouraged to choose a problem that could in some way be linked to the scientific topic of the module. They are given the assignment to carefully define and elaborate the problem ("why is it a problem"), and to locate it in the context of complex systems, involving not only scientific and technological aspects but also social, ethical, environmental and economic dimensions. In this exercise, students draw mind maps to identify a variety of stakeholders, causal relationships, feedback loops and leverage points. These first phases of the FOSE approach can tap effectively into the "base elements" of the social identity processes described in the SIMPEA: the identification of a collective crisis, the appraisal of the problem and the sharing of emotions and motivations as well as norms and goals through value discussions and collective systems thinking.

After laying this groundwork for their collective futures thinking, the groups then practise scenario development techniques to create several different imagined trajectories of how their chosen problem might evolve with the surrounding society. Students are guided to employ, in turns, three fundamentally different types of thinking methods commonly used in Futures Studies: probable, possible and preferable futures (Börjeson et al., 2006). Such scenario-thinking activities are particularly well-suited for SE since science and technology play major roles in (young) people's images of the future and their expectations, fears and ideals (e.g., Rasa et al., 2023).

The last of the three scenario building exercises in the FOSE approach, the imagination of preferable futures, can contribute strongly to the collective identity process through intense discussions on shared values, norms and goals. Students collectively envision a future not by following the current trends or possible trajectories but instead by starting from their own values and hopes and negotiating to find a shared dream. After finding it, they are guided to 'leap' in their minds into that future, imagine themselves there and contemplate what else has changed in the system now that their sustainability problem has been solved. In the final exercise of FOSE modules, the students create a route to their preferable future. This exercise employs the backcasting technique (see e.g., Börjeson et al., 2006), i.e., going step-by-step backwards from the preferable future to the present, recognising what phases and obstacles were encountered along the way and how they were overcome through collective action. According to feedback, students have found the backcasting activity in the FOSE courses particularly empowering for action (Levrini et al., 2021), thereby holding the potential to effectively promote collective efficacy. The modules end with a closing seminar imagined to take place in the future. In the seminar, the groups present their success stories in the past tense: how did we together solve the societal problem and what kind of roles did each of us play in the process? The reported empirical findings (Levrini et al., 2021) imply that this collective work for a shared purpose increases students' belief that their group's actions can be effective and have an impact on the crisis (collective efficacy) and also fosters their social identification as a member of a group

building a more sustainable future (ingroup identification). The empirical findings from the FOSE implementations, reported elsewhere (Hyyppä et al, 2024; Levrini et al., 2021; Rasa et al., 2022) imply that the approach has been highly valued among students and seems to contribute not only to students' individual but also their collective sense of agency, perceptions of the future, systemic understanding, futures thinking skills and value discussion in the context of local and global sustainability issues. Thus, we argue that the FOSE approach seems very promising for collective identity processes in SE.

To summarise, FOSE holds the potential to support the following SIMPEA components: ingroup norms and goals, collective efficacy, and ingroup identification. By inviting students to collaboratively envision desirable futures and work backwards to chart pathways to change, FOSE encourages shared goal setting and value clarification within learning groups. These imaginative exercises not only can promote systems thinking, a key complement to appraisal, but also provide structured opportunities for students to experience themselves as part of a forward-looking, purposeful collective. In doing so, FOSE opens up possibilities to enhance students' motivation to act together and belief in their collective impact on the future, reinforcing their climate-related social identity and their sense of agency.

PET 3: Teaching Causal Knowledge of Climate Change

Causality, and more specifically causal knowledge, plays a significant role in dealing with CC (Tasquier & Pongiglione, 2017).

Causality is fundamental for understanding how events and phenomena are related in time and space, especially in context of the climate crisis, explaining how and why things happen, making predictions, identifying patterns, and designing strategies to address problems and/or to achieve desired outcomes (Pearl, 2009).

Within SE research, causal reasoning remains a topic of paramount importance: Understanding causality is essential for constructing scientific explanations (Chi, 2005), engaging in scientific inquiry (Hmelo-Silver et al., 2007) and moving from simplistic to more complex system-oriented models (diSessa, 2014). Integrating causal reasoning into SE also fosters interdisciplinary connections, showing how changes in one system can affect others (Levrini et al., 2021) This holistic view is crucial for addressing global challenges like CC, which require engagement with interdisciplinary content and the analysis of complex problems (Tasquier & Pongiglione, 2017).

Causal knowledge is also particularly relevant for understanding and promoting pro-environmental behaviour. The empirical work presented by Tasquier and Pongiglione (2017) demonstrated that scientific knowledge focused on clarifying causal relations within climate dynamics can make humans understand their interactive role within the environment, especially the influence that human agency can have in "natural" causal dynamics, where the role of humankind cannot be considered only as a mere observer (Tasquier et al., 2016, 2022). Furthermore, it was demonstrated that – in order to trigger willingness to take pro-environmental actions – it is not knowledge per se that is needed (*an understanding of the essential features of the climate system or greenhouse effect*) but causal knowledge (*the exploration of the many causal relationships and the emphasis on the individual role in the complexity of climate dynamics*). According to this specific principle, a particular activity was designed and implemented (Tasquier et al., 2019). The activity aimed to distinguish between linear and circular causality, within scientific texts about a present issue, recognising the nature of the causal links and individuating possible feedback loops that

can be found starting from the text. Students were required to read the text, identify the problems within the text, organise and hierarchise them, find the cause-effect links among them, draw the map by making explicit the reasoning beyond the arrows that connect the problems, and search for crucial points in which it is possible to identify or create feedback loops (Tasquier et al., 2019). The analysis carried out on the data collected from several implementations showed that the students consciously developed special *structures*. These structures served to organise the fragmented and chaotic reality of the present by selecting pieces of information from among the indistinguishability of the background; organising pieces of information into relations that can be hierarchical, causal and temporal; and by distinguishing logical codified structure of reasoning among them (Tasquier et al., 2019). These skills are needed to build a picture of a problem by extrapolating and organising dimensions, clusters, and values which are usually interconnected in a complex problem, without projecting "ideological aspects" in the issue a priori but only posteriori, i.e., in the step forward toward searching for an action and solution space (Levrini et al., 2021).

When students engage in activities that link human actions to CC, they perhaps develop a shared understanding and appraisal of the climate crisis. Discussing, based on causal knowledge, possible effective actions, such as conserving energy or advocating for policy changes, may contribute to the development of collective efficacy beliefs, particularly when grounded in a shared understanding of the crisis and its possible solutions. This PET offers opportunities to understand the climate crisis as a complex collective challenge through systems thinking: understanding the underlying mechanisms of CC, especially human-induced causes and systemic feedback loops, may help learners grasp the crisis as a shared problem requiring shared solutions. When taught in collaborative settings, this kind of causal knowledge could foster a collective "we" perspective by clarifying how individual and group actions are embedded in broader cause-effect relationships. In this way, causal reasoning may provide a cognitive foundation for recognising shared responsibility and agency, supporting the emergence of pro-environmental ingroups committed to action.

PET 4: Philosophising and Argumentation with Children

Engaging with questions of meaning and being, exchanging ideas with others in a critical-reflective dialogue, identifying valid arguments, initiating a search for understanding can all be seen as fundamental aspects of philosophical practice in the philosophical Community of Inquiry (COI; Sharp, 1995). Participants of a COI engage in structured, discursive dialogue, which itself represents philosophical practice (Cassidy, 2021). The COI facilitates reflective thinking and the strengthening of judgement in discourse with one another, which is a shared search for orientation (Martens, 2018) and thus a connection to social identity formation.

Studies show that Philosophising with Children (PwC) promotes critical thinking through dialogue, even in early education (Daniel et al., 2016). PwC can facilitate the promotion of critical science learning and is associated with scientific literacy as it is characterised by discourse about the nature of science, critical thinking and critical-reflective decision-making (Almeida et al., 2023). Hodson (2010) summarises in Vision III of scientific literacy the conceptual idea that supporting the formation of one's own opinion, critical questioning and the development of collective values are the basis for collective agency. This is also a key aspect of PwC: "To be a participant in a community of philosophical inquiry is to learn to see oneself in relation to the other and to reflect on thoughts that are other – to that which is not oneself" (Sharp, 1995, p. 48). This is an important point for the

development of social identity (processes), as the willingness to understand and communicate with each other might enable the negotiation and development of shared norms and goals. Reflecting and discussing these norms and making them explicit could be a leverage point to promote ingroup identification within the COI. According to the COI approach, learners must explore normative information in a participatory way, especially with regard to early (critical) SE. The COI as a *philosophising we-group* represents an opportunity for social identity formation through identification of the learners with this group, the joint search for orientation and shared norms and goals, and the disclosure of assumptions and reasons. In relation to CC, Krug (2023) emphasises (in the context of PwC) the importance of a critical-reflective orientation towards climate ethics discourses for the formation of shared values and the exploration of a human–environment relationship, the goal of which can be the search for reasons for a good life.

To illustrate how philosophising and argumentation can be incorporated in educational practice the approach of a philosophical workshop for the classroom is exemplified. Primary school children aged eight to nine participated in a journey through time on the topic of "Futuropia – the world in 100 years" (Krug & Maier, 2022). It is based on Martens' five-finger model, which includes the flexible and differently applicable philosophical methods of phenomenology, dialectics, analytics, hermeneutics and speculation (Martens, 2018). At the beginning, the children of the COI 'travelled' together in a time machine. They were then asked to write down their questions about the future. In think-pair-share mode, these queries were initially discussed. The children then had to develop questions that were meaningful to them independently of the teacher, who acted as a "facilitator and co-inquirer" (Bleazby et al., 2022, p. 1100). The questions were clustered, dialectically examined and jointly crystallised into generic terms: the aspects of *environment/nature*, *technology*, and *time* were among those important to them, and were discussed in a hermeneutic and analytical phase. The question *"How will technology affect our lives?"* was explored in a further dialogue in which the children chose one of several thought experiments that addressed the critical, techno-philosophical question of optimising human existence through technology. This is a speculative method that serves as a catalyst for philosophical conversations and can have a heuristic, epistemic and illustrative function through creative speculation and the testing of assumptions (Pölzler & Paulo, 2024). For example, it was clear to the children that technology must not have an excessive impact on humanity and its behaviour towards the environment, even if it offers considerable benefits (Krug & Maier, 2022). This process of shared orientation can be viewed as an expression of critical decision-making. The opportunity to support shared norms and goals lies in the fact that "the COI can help such students better understand why their position is considered unreasonable by others, which may moderate their views and render the student more open to collaborating with others who hold different views and, also, more likely to revise their beliefs in the future" (Bleazby et al., 2022, p. 1101).

In conclusion, PwC "[…] presents a safe environment in which [learners] might explore and practise engaging with ideas of their own and others" (Cassidy, 2021, p. 21). This might enable children and young learners to explore shared values in the context of CC, a good life and possible futures, as well as to pursue shared values for the COI. This approach engages students in reflective dialogue and co-construction of meaning, encouraging the development of ingroup norms and goals and ingroup identification through shared ethical inquiry. In a COI setting, students are encouraged to explore questions about values, futures, and justice, which helps them recognize themselves and their peers as part of a deliberative, ethical collective. The open-ended, participatory nature of PwC can be viewed as a process of collective orientation and mutual understanding, key ingredients for

the development of a value-based social identity. When oriented toward climate ethics, this process may shape students' motivation to act on shared norms and support group-based action for sustainability.

PET 5: Role-Play Simulations of Climate Negotiations

An educational role-play is "a type of simulation whereby participants act out the role of a character in a particular situation following a set of rules" (Rao & Stupans, 2012, p. 427). Sterman et al. (2015) as well as Öhman and Öhman (2013) created role-plays in which groups of students represented different countries during a simulated UN climate negotiation. The different countries were chosen by the game designers to have divergent interests and goals in the negotiations. Countries of the global north, for example, have contributed the most to CC due to their historical greenhouse gas emissions, while countries of the global south have contributed much less to CC but many of them suffer more from the consequences than historically high-emission countries (IPCC, 2023). States in the global north have a high interest in continuing to burn fossil fuels because for example their economies are heavily dependent on cheap energy from such resources. Countries in the global south, on the other hand, want appropriate compensation payments both for their damages due to CC impacts and for renouncing the use of fossil fuels in the future. Activist groups can be included as an additional role in the role-play in order to show the potential actions that students can take. To stimulate an engaging debate that reflects the complexity of international climate politics, it is crucial that the roles represent divergent interests. The divergent roles allow students to understand multiple perspectives on climate politics and to change roles. However, an analysis of students' discourse during the role-play by Öhman and Öhman (2013) shows that creating a controversial discussion is challenging because students tend to pursue consensus and harmony-oriented discussions and avoid ideological conflicts. Therefore, time and effort must be invested in a role briefing before the simulation. Students need detailed information about the interests and aims of the role they are representing, as well as arguments to use during the negotiation.

A typical simulation opens with a ceremonial speech, proceeds through one or more negotiation rounds, and concludes with an agreement and a structured debrief. After each round, Sterman et al. (2015) used climate model projections to give students feedback on the probable climatic and socio-economic consequences of their proposed measures. Typically, these projections show that initial pledges are insufficient and the need for more ambitious goals in subsequent rounds.

Role-plays, which simulate UN climate negotiations, can support collective efficacy beliefs related not only to the learning group but also to humanity in general, because they simulate cooperative problem solving on a global level (Etzkorn & Reese, 2022). Furthermore, during the role-play students' shift from a distributive, blame-oriented negotiation to emphasising common interests of all countries in limiting the risks of CC (Sterman et al., 2015). Experiencing common interests and values is crucial to fostering identification as a global citizen (Etzkorn & Reese, 2022), which can stimulate private and public sphere action to protect the living conditions of humanity. In addition to these mediating effects on climate action via social identity processes, climate negotiation role plays might also influence the appraisal and action of students directly. Experiencing and understanding the role of politics in mitigating and adapting to CC can lead students to apprise CC not only as a scientific issue but also as a socio-political issue (Zeidler, 2015). Furthermore,

understanding the role of climate politics in mitigating CC seems to be beneficial in moving students towards taking and supporting political actions that strengthen their collective agency (Kranz et al., 2022). These arguments demonstrate that simulating UN climate negotiations in role-plays is a PET because this approach might stimulate various social identification processes that are relevant for initiation of appropriate appraisal and action in the context of CC. However, role-plays are also promising in the facilitation of scientific literacy and scientific knowledge in political processes that are related to moral challenges. During the role-play, scientific knowledge about the climate system is crucial for understanding the consequences of the agreement reached, while at the same time the relevance of scientific knowledge is visible through its impact on the political negotiation process (Sterman et al., 2015).

Synthesizing Key Elements of Social Identity Formation in Science Education on Climate Change

In this section, we synthesise recurring elements across the five PETs to identify pedagogical patterns that align with the social identity processes described by SIMPEA, highlighting potential entryways for fostering collective agency in SE. First, all five approaches use some sort of speculative projections in the future by discussing possible or desired futures. These projections are based on or contrasted with complex (causal) scientific knowledge about the climate system, technologies or consequences of CC. Speculative future scenarios may foster ingroup identification when they frame students as members of a shared generation or social group that will collectively experience and can collectively shape the future. This is particularly the case when such scenarios are co-constructed in group settings and tied to narratives of shared agency or responsibility. Second, many of the PETs link scientific knowledge to socio-political issues such as justice, responsibility and participation, as students collectively reflect or even act on what a just or sustainable future might look like. Rather than teaching predetermined values, the learning environments described above encourage students to co-construct these goals in dialogue with each other, which can facilitate the formation of shared norms and goals. Third, the PETs typically include open-ended and participatory formats, such as role-plays, collaborative projects or group discussions that encourage collective decision-making. These formats are constructive as they focus on decision-making, problem solving, or desirable futures as opposed to negative scenarios. They are open-ended as they refer to scientific knowledge but not to scientifically determined scenarios, and the students can for example decide which scenarios they discuss, or actively support. This can be viewed as an important stepping-stone to support collective efficacy beliefs as they are built on the expectation that the group can reach their self-determined (positive) goals (Hamann & Reese, 2020). Fourth, a recurring element in the PETs is that learners are provided with opportunities to develop and evaluate their own point of view, while at the same time maintaining an open-minded approach to diverse perspectives, with the aim of seeing oneself in relation to others and vice versa. These dialogical practices could be helpful to establish a sense of relational positioning within the group, as a basis for ingroup identification and the negotiation of shared meaning and norms. Moreover, the opportunity to see oneself as part of a broader collective identity, whether based on youth, locality, or global citizenship, opens up opportunities to shift from individual concern to collective responsibility in SE.

Experiencing such critical-reflexive approaches and possibilities of active engagement in the school context can be seen as an important prerequisite for group identity and collective efficacy and constitutes a participatory-democratic practice. Overall, these direct and indirect regional, temporal and social notions of agency can bridge space and time, and reduce the temporal, social and geographical distance towards the climate crisis that affects and requires one's social self (Masson & Fritsche, 2021).

Discussion

In this conceptual paper, we explored how SE in the context of CC can promote collective agency by addressing key social identity processes such as ingroup identification, collective efficacy, and shared norms and goals. Drawing on the Social Identity Model of Pro-environmental Action (SIMPEA; Fritsche et al., 2018) and its extension to systems thinking (Reese et al., 2020), we analysed five educational approaches that exemplify these dynamics. We proposed these as Principles of Education for Transformation (PETs): pedagogical configurations that aim not only at change, but also at enabling it through social identity processes. After synthesizing key elements of the PETs, we now reflect on the implications for SE research and practice.

Despite the diversity and contextual differences of the five identified approaches, all align with multiple social identity processes proposed by the SIMPEA. This is significant because the approaches were not originally designed based on the SIMPEA or intended to facilitate social identity processes. Using this model as a lens to compare and analyse very diverse educational approaches within SE highlights potential patterns for fostering collective agency. This demonstrates the model's applicability across different contexts and its potential to serve as a conceptual framework to guide an overarching approach to SE on CC aimed at promoting action. This is relevant for SE because there is general agreement on desired learning outcomes connected to the Vision III (Sjöström, 2024) or agency in the Anthropocene (Bianchi et al., 2022; White et al., 2023), whilst it is less clear which learning processes and theories should be used to achieve these objectives.

Currently, SE on CC refers predominantly to theories that describe behaviour changes of individuals such as the theory of planned behaviour (Ajzen, 1991). This is not surprising as recent reviews found that educational approaches in research and practice focused almost exclusively on individual agency (Kranz et al., 2022; Monroe et al., 2019). However, we believe that this reliance on individualised theories of behaviour change will lead to education that is inadequate to mitigate or adapt to CC and, even more so, it contributes to the preservation and continuation (if not also consolidation) of existing socio-political conditions and structures. Kranz et al. (2022) already argued that individual actions are insufficient to mitigate CC because, for example, only a small fraction of global greenhouse gas emissions are related to individual behaviour and because the ability of an individual to act depends on political and socio-economic conditions. In this regard, the SIMPEA offers another argument why relying on theories that focus on individual behaviour is problematic: private and public sphere actions of individuals are influenced by social identity processes (Fritsche et al., 2018). SE aimed at contributing to the mitigation and adaptation to CC should therefore shift from an individual to a collective emphasis on action, as the SIMPEA suggests.

Moreover, the SIMPEA offers new interesting research questions related to the processes that lead students to act as a result of their education. Drawing a direct link between actions (or no-actions) of individual students and education is challenging because specific student actions such as saving energy or participating in a pro-environmental protest can have multiple personal causes, some that can be influenced by education (e.g., knowledge and skills, collective efficacy beliefs) and others are hard or impossible to change through education, such as monetary or time resources or power structures (Lange, 2024). Thus, it might be more fruitful for further research to investigate the causes that influence private- and public sphere actions and that can be affected by education such as the identity processes proposed by SIMPEA. Alternatively, researchers can take a collective perspective by analysing the outcomes of collective approaches and their impact on students, e.g., in terms of the scale, frequency or consequences of student climate protests or student-driven changes towards zero-emission schools (e.g., Keller et al., 2024). By linking the outcome of collective actions to students' identity processes and systemic factors such as socio-political context, school climate and power structures, further research can investigate how education, identity and society interact in specific learning environments. At the very least, the SIMPEA can inform design-based research projects and teaching practices, as it highlights identity processes that could be emphasised in education. Based on the SIMPEA, existing teaching approaches (like those we have discussed) can be optimised to enhance collective agency. For example, teachers too can reflect with students on the fact that they reached agreement during a simulated UN climate negotiation because their negotiations were based on the common interests of all countries in limiting the risks of CC. As argued in PET 5, such explicit reflection can increase the experience of collective efficacy.

In sum, this conceptual paper explores five diverse PETs through the lens of the SIMPEA and thereby highlights that SE can strengthen collective agency in the climate crisis when it (i) couples robust scientific understanding with socio-political deliberation, (ii) offers opportunities to experience successful joint action and (iii) nurtures inclusive "we-identities" that transcend the classroom.

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