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2022-03-31

Laherto , A & Rasa , T 2022 , ' Facilitating transformative science education through futures thinking ' , On the Horizon , vol. 30 , no. 2 , pp. 96-103 . https://doi.org/10.1108/OTH-09-2021-0114

http://hdl.handle.net/10138/345154
https://doi.org/10.1108/OTH-09-2021-0114

Facilitating transformative science education through futures thinking

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Abstract

Purpose – *The aims and pedagogies in the field of science education are evolving because of global sustainability crises. School science is increasingly concerned with responsible agency and value-based transformation. The purpose of this conceptual paper is to argue that perspectives and methods from the field of futures studies are needed to meet the new transformative aims of science education for sustainable development.*

Design/methodology/approach – *This paper analyses some contemporary challenges in science education and gives reasons for introducing a futures perspective into science classrooms. The suggestion is illustrated by reviewing some results, published elsewhere, on future-oriented activities trialled within the European Union project ''I SEE'' and students' experiences on them.*

Findings – *Recent research has shown that future-oriented science learning activities, involving systems thinking, scenario development and backcasting, can let students broaden their futures perceptions, imagine alternatives and navigate uncertainty. Practising futures thinking in the context of contemporary science offers synergies through shared perspectives on uncertainty, probabilities and creative thinking.*

Originality/value – *This paper highlights the relevance of the futures field for science education. Future-oriented activities appear as promising tools in science education for fostering sustainability, agency and change. Yet, further work is needed to integrate futures aspects into science curricula. To that end, the paper calls for collaboration between the fields of futures studies and science education.*

Keywords *Agency, Education for sustainable development, Futures thinking, Science education, Transformative learning*

Paper type *Conceptual paper*

Received 30 September 2021
Revised 10 January 2022
20 February 2022
Accepted 21 February 2022

The authors thank the colleagues of the projects" I SEE" and" FEDORA", both coordinated by Olivia Levrini, University of Bologna, for their support in the development the approaches discussed here. The module that was discussed as an example was developed by Arto Hellas, Johanna Jauhiainen, Timo Kärkkäinen, Elina Palmgren, Tuomas Puranen, Tiina Ranta-aho, Kimmo Tuominen and the authors of this article with the support by the European Commission Erasmus+ programme under Grant Agreement No. 2016–1-IT02-KA201-024373.

Science education in transformation

The aims and pedagogies in the field of science education [1] are taking new directions. International recommendations for science curricula have long shifted their focus from learning science content and concepts to learning skills and competencies. This global trend is reflected in the changing meaning of *scientific literacy* (Roberts and Bybee, 2014). A few decades ago, the term mostly referred to conceptual knowledge of science. Nowadays, especially in developed western countries, it is understood as a civic skill – a functional competence to use scientific knowledge in everyday situations and social matters. This trend is evident, for example, in the PISA program (OECD, 2019) which has a high international impact on education systems. Similarly, the European Union (EU) has emphasised social issues and responsibility in its recommendations for science education (European Commission, 2015; Rocard *et al.*, 2007) and by bringing the idea of responsible research and innovation to schools (Laherto *et al.*, 2018).

During the past decade, the purpose of science education has continued to evolve amid the global upheaval of all education because of the growing realisation of global sustainability crises. Education plays a key role in the global endeavour towards the Sustainable Development Goals set by the member states of the United Nations in Agenda

2030. Responding to sustainability crises is believed to require a fundamental rethinking of the values, purposes and methods of education (Lotz-Sisitka *et al.*, 2015). Education for sustainable development (UNESCO, 2017) implies holistic and transformative learning through interactive, action-based and learner-centred pedagogy that aims to bring about change in both the learner and, ultimately, society (Hodson, 2011). Somewhat similar demands have been voiced by the Organization for Economic Co-operation and Development (OECD), whose policy paper "The Future of Education and Skills" (OECD, 2018) states that schools should prepare young people for professions, technologies and problems that do not exist yet. Students need to learn to navigate uncertainty, act responsibly and foster the well-being of individuals, communities and the planet.

Science education has a special role to play in implementing these new goals. Technology is developing at an accelerating pace and people are increasingly confronted with issues related to science and technology at personal, social and global levels. Climate change and other sustainability crises, as well as related concerns and solutions, have a particularly strong scientific component.

Therefore, over the past decade, a number of demands have been made that science education develop more reflexive and radical goals than the vision of scientific literacy discussed above. Typical teaching approaches based on socio-scientific issues (SSI) and science–technology–society–environment connections (Zeidler, 2014) have been criticised as superficial, politically naive and therefore ineffective in bringing about the necessary individual and societal change (Hodson, 2003, 2011; Sjöström *et al.*, 2017). In sustainability education, it is not sufficient to learn scientific concepts or how to apply them in real-life contexts; science education must also directly support value-based change in both individuals and society. Such a critical approach to science education (Sjöström *et al.*, 2017) involves the idea of the transformativity and transgressiveness of learning (Lotz-Sisitka *et al.*, 2015). This corresponds to the goal of raising young people who are ready and willing to take action to mitigate or resolve sustainability crises and other societal problems (Bencze *et al.*, 2012; Hodson, 2011). Fostering *agency* (Emirbayer and Mische, 1998) of the young is widely recognised as a key objective of science education.

Potential of futures thinking for science education

The premises and methods of futures studies have many similarities with the goals of sustainability education set by both UNESCO (2017) and the OECD (2018). Anticipatory competence, as addressed in education for sustainable development, connects to imagining diverse futures and relating them to one's own wishes (UNESCO, 2017, p. 10). The learning framework by the OECD also emphasises the importance of futures thinking in sustainable development: responsible action requires anticipation and reflection (OECD, 2018). Research has shown that young people's positive thinking about the future and possibilities to influence it tends to be limited to the near future and the local level (Cook, 2016), with one's own future often considered separate from the future of the world (Threadgold, 2012). Thus, strengthening futures thinking may support students' altruistic dispositions in addressing the needs of future generations globally (Lloyd and Wallace, 2004), which is at the core of education for sustainable development.

One's agency is intertwined with how one thinks about the future (Carabelli and Lyon, 2016; Cuzzocrea and Mandich, 2016). In the seminal conceptualisation of agency by Emirbayer and Mische (1998), the *projective dimension* of agency is characterised by the ability to momentarily detach oneself from thought-limiting assumptions and schemas to imagine desirable futures based on values and wishes. In futures studies, several methods for that purpose have been developed. Such methods, like visioning and *backcasting* (Bishop *et al.*, 2007; Robinson, 1990), may thereby support the development of agentic orientations. Transformative action, called for by the new aims of science education, requires projective and transformative agentic orientations.

There are several reasons for discussing futures specifically in science education. In general, issues around sustainability, agency and critical thinking overlap considerably with *futures literacy* (Häggström and Schmidt, 2021) and the current interpretations of *scientific literacy* (Sjöström *et al.*, 2017). Societal futures should be addressed in science classrooms also because the majority of students' deterministic and dystopic fears are related to science and technology (Carter and Smith, 2003). Somewhat paradoxically, science and technology also relate in many ways to young people's aspirations and dreams of more sustainable futures (Cook, 2016; Lloyd and Wallace, 2004; Rasa and Laherto, 2022). Indeed, future-oriented teaching can help students assess the positive and negative impacts of science and technology on society and the environment and deepen their understanding of the complexity of these interactions.

Research on science teaching has shown that future aspects arouse interest in the widely used SSI approach (Osborne and Collins, 2000). Moreover, future perspectives may increase not only the relevance but also authenticity of science education (Kapon *et al.*, 2018). The future is inherent to the nature of science: modelling and prediction are essential in the epistemology of science (Branchetti *et al.*, 2018; Levrini *et al.*, 2019), and understanding the differences between linear causal models, probabilistic models and complex systems is crucial in making predictions. In addition, creativity and imagination play a key role in both science and its learning (Hilppö *et al.*, 2017).

In spite of these many reasons for addressing the future explicitly in science education, the typical approaches in science curricula either pass over the temporal dimension or are oriented towards the history of science (Stuckey *et al.*, 2013). The scarcity, superficiality and simplicity of futures discussion may stem from educators being careful not to increase students' concerns and anxiety, and therefore passing over the uncertainty and openness of the future. Such teaching is, however, hardly optimal for developing students' views on the future and the potential roles of science and technology in it (Carter and Smith, 2003; Lloyd and Wallace, 2004).

Therefore, during the past decade some scholars have suggested incorporating futures aspects into science education, with a few initiatives launched to that end. Jones *et al.* (2012) took the SSI approach as the basis for their conceptual framework designed to support teaching that fosters futures thinking (see also Buntting and Jones, 2015). The framework incorporates five elements that are typical of scenario building in futures studies: understanding the current situation, identifying trends, analysing the causes of change, developing possible and probable futures and ultimately choosing desirable futures (Jones *et al.*, 2012). Lloyd and Wallace (2004) and Paige and Lloyd (2016) have also developed a future-oriented approach to science education that provides students with broader perspectives, especially by guiding them to identify and imagine alternative, more socially and environmentally sustainable futures. A similar approach was developed in the EU funded project "I SEE" (Branchetti *et al.*, 2018). In the next section, we review the developed teaching methods and results from that project.

Examples of future-oriented pedagogies in science education

To illustrate the above ideas, this section briefly presents the future-oriented science education approach developed in the "I SEE" project. After the presentation of teaching methods used, we give a brief review of students' experiences. The activities and results are comprehensively reported elsewhere (Levrini *et al.*, 2021; Rasa *et al.*, 2022). Here, the methodology of the studies is referenced only in outline, as our purpose is only to comment on the practical feasibility and potential benefits of future thinking in science lessons. The teaching materials briefly presented here are available in their entirety on the project website (iseeproject.eu).

The "I SEE" (Inclusive STEM Education to Enhance the Capacity to Aspire and Imagine Future Careers) project, funded by the EU's Erasmus+ program and carried out in 2016–2019, sought to address the difficulties many young people have, because of the climate crisis and accelerating social change, in projecting themselves into the future (Branchetti *et al.*, 2018). The pedagogy of the project applied the action competence approach alongside perspectives and methods developed in futures studies. The "I SEE" partners in Iceland, Italy and Finland developed modules for upper secondary school (16–19-year-old students) that combined futures thinking and sustainability aspects with current science-related societal issues: the topics of the developed modules were climate change, artificial intelligence, quantum computers and carbon sequestration. The following examples are from the module developed in Finland, titled "Quantum computing and the future of ICT" (full description of course activities is available at iseeproject.eu/i-see-final-intellectual-outputs/).

The module covers topics ranging from basic quantum physics and quantum algorithms to futures and systems thinking skills, attempting to present a continuity between fundamental science and the future. While studying the conceptual and procedural aspects of the central scientific domain, students chose a societal problem that interested or worried them. During the module the students developed their problems into "future projects" in small groups of three to five students. Typically, students chose environmental, social or economic sustainability issues, all relevant themes in sustainability education. The problems and their possible solutions were worked on in guided activities that involved creative thinking, problem definition and mapping, systems thinking, finding opportunities to influence and scenario development – all in the context of the scientific topic of computing and ICT. The activities were based on approaches in futures studies and aimed at understanding the plurality of futures, detaching from deterministic thinking, identifying and questioning assumptions and learning that small changes can become large system-level changes over time. Students were guided to practise three different ways of thinking about the future and to develop probable, possible and preferable future scenarios (Bishop *et al.*, 2007; Börjeson *et al.*, 2006) for their chosen problems. At the end of the course, the small groups shared their "future projects" based on their envisioned preferable scenario: a solution to a social problem, partly related to the scientific topic but requiring system-level scrutiny. These presentations were constructed using the backcasting method (Bishop *et al.*, 2007; Robinson, 1990): students leapt into the future of their preferable scenario, imagined living in that future and then worked backwards to discover a sequence of events leading to it. At the final seminar of the course, which was imagined as taking place in 2040, students told their "success stories" in the past tense: how it all happened, what stages and obstacles there were along the way, what roles they each had in solving the problem and who they needed help from.

The "futures activities" were carried out interlocked with studying the scientific content. This interplay allowed the module to tap into a fruitful synergy in lines of reasoning between quantum physics and futures thinking: both domains require a certain mental leap of escaping the shackles of everyday thinking, opening up new perspectives on uncertainty and probabilistic thinking and sparking wonder of what lies beyond the limits of current knowledge.

Two types of data were collected and analysed in the context of the module: students' essays entitled "Typical Summer Day in 2040" written prior to the course and individual interviews approximately a week after the course. In this way, the project enabled us to analyse, through inductive, qualitative content analyses, students' initial ways of futures thinking as well as their perceptions of any changes in their thinking during the course. The methodology and results of empirical studies are reported elsewhere (Rasa *et al.*, 2022; Rasa and Laherto, 2022); here we only review some observations relevant to this article.

Students' preliminary essays showed both optimistic and pessimistic prospects for the global future. Threats and fears were linked to climate change, social inequality, unemployment, technology misuse, overpopulation and resource depletion. Students had high expectations of solutions delivered by science and technology to sustainability problems, but rarely envisioned their own role in these solutions. However, based on content analysis of the interviews, the students developed more positive visions of the future during the course, learned to think more diversely and open-endedly about different future scenarios and found new opportunities to influence both their own and the global futures. The backcasting method was perceived as particularly empowering. The course helped students to find career options that integrate science and the humanities and to imagine professions that do not yet exist. In the interviews, students reflected that the future had become "within reach" or "more real" and that they would continue to use the scenario and systems thinking techniques they had learned. They reported feeling empowered and hopeful after working together to find ways towards a desirable future. Students also reported seeing the role of technology in the future in a more diverse way, realising that technology can be actively developed to address human and social issues. In general, upper secondary school students learned to think about science, technology, complex systems and their own futures in a way that they felt was neither normally present in science nor in other school subjects.

Discussion

Based on students' experiences, it seems that the future thinking activities trialled in the project are able to implement the goals of transformative science education for sustainability education: they can provide functional and learner-centred pedagogy that aims for responsibility and facilitates change in both the learner and society (Hodson, 2003, 2011; Lotz-Sisitka *et al.*, 2015). Because how one perceives the future so deeply affects how one acts at the present (Carabelli and Lyon, 2016; Cuzzocrea and Mandich, 2016), the results we have summarised here have plausible implications for students' agency. The participating students' agentic orientations (Emirbayer and Mische, 1998) could develop as they found new opportunities to influence personal and collective futures, imagined future professions and generally began to feel more in touch with the future. The students also considered it important that reflecting on hopes and worries about the future was done together with others. Indeed, the group work activities seemed to support shared agency, which Roth and Lee (2004) have suggested as a goal and perspective for science education.

The results discussed here are also in line with previously reported initiatives in science education using the concepts and tools from futures studies. For example, Jones *et al.* (2012) reported that 8–18 year olds learned through these types of activities to identify changes, trends and cause–effect relationships and to elaborate on potential and desirable futures. The results of the "I SEE" module seem to support the basic argument of futures researchers that thinking about alternative scenarios broadens future perceptions and prepares for an uncertain future (Bishop *et al.*, 2007). Participants have found the "I SEE" courses to be interesting and inspiring (Levrini *et al.*, 2021; Rasa *et al.*, 2022), and the same has been observed in previous experiments combining scenario building activities with science education (Buntting and Jones, 2015; Jones *et al.*, 2012).

It must be noted, however, that the group of participants in the course was not a representative sample of upper secondary students: they enrolled voluntarily and were thus already interested in information technology and developing their futures thinking. The activities need to be tested with wider groups of students. Furthermore, connecting futures pedagogies to science and bringing futures thinking into educational policy documents and curricula demands additional work. Collaboration between science educators and futures researchers would be particularly welcome to that end. Integration of future-oriented activities in science curricula and lessons will also need to be worked on in collaboration with teachers. We are currently starting such a process in the context of a new project, "FEDORA" (www.fedora-project.eu), which is a continuation of "I SEE".

We can, however, already see that the future-oriented approach seems to provide tools for the needs of science education presented in this article. Many features of transformative science education can be seen in this approach (Sjöström *et al.*, 2017). The students participating in "I SEE" examined societal issues that involve aspects of science, humanities and technology as facets in holistic and complex systems, emphasising the importance of values, choices and active participation in bringing about change towards a more sustainable future. The solution-oriented approach and futures thinking techniques applied in the course seemed to support students' agency and ways of coping with uncertainty, as well as their curiosity and critical thinking around contemporary challenges and emerging science and technology, reflecting what we regard as central aims of science education in the present and for the future.

Note

1. We refer to *science education*, both as a field of practice and research, in its broad sense including education on science subjects at all levels of schooling and encompassing the role of technology in society and daily life (cf. Roberts and Bybee, 2014).

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