FEDORA

FR3:
Framework to futurize science education

FEDORA - Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty
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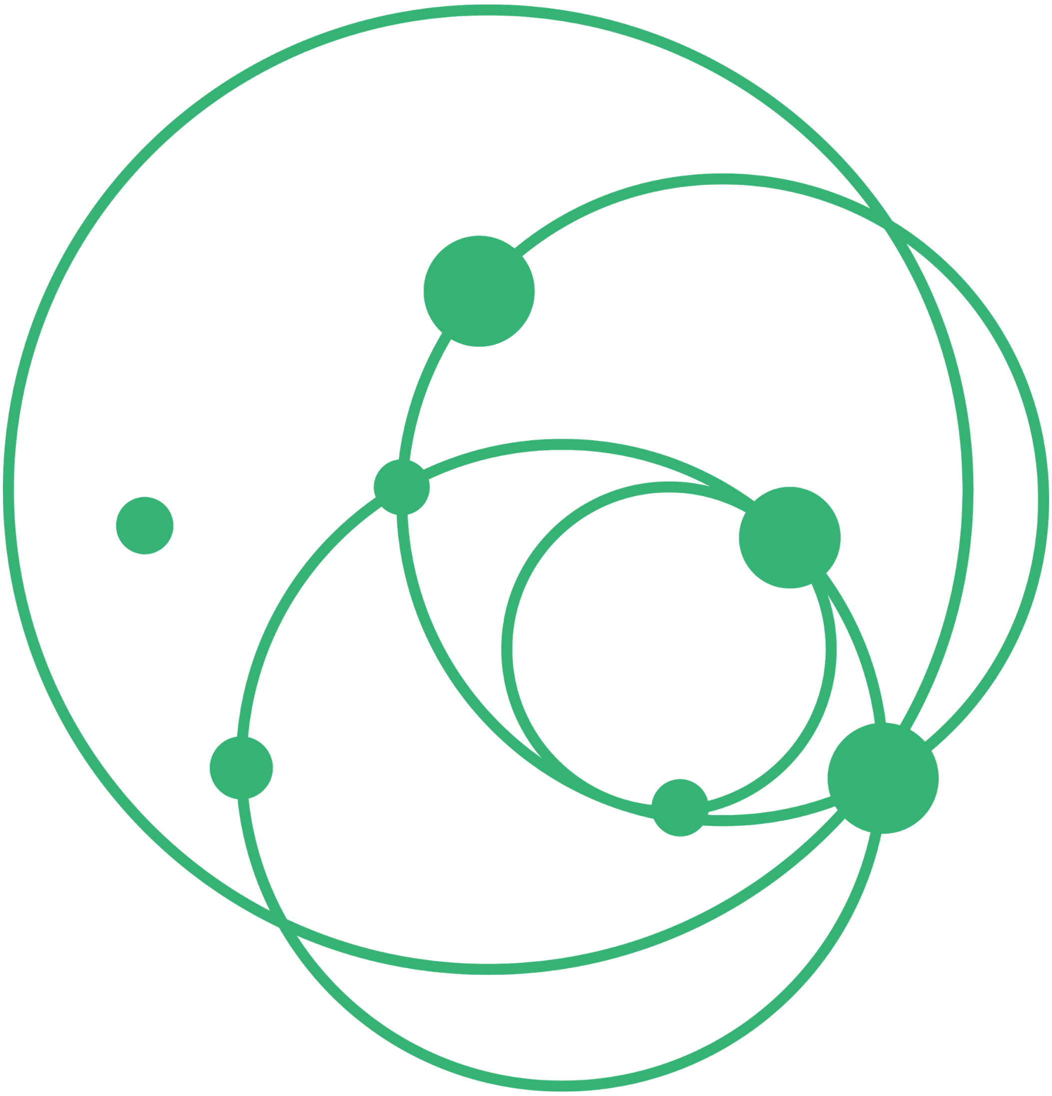

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1. Introduction

Global sustainability crises and accelerating societal and technological developments are posing new demands for science education research and practice. A lack of stable future horizons can lead young people to regard the future with hopelessness, to take directionless actions and to exhibit inabilities to project themselves into the future (Cook, 2016; Rosa, 2013; Rubin, 2013). Meanwhile, the United Nations' Agenda 2030 programme calls for societal transformations that cannot be achieved without transgenerational thinking, responsibility and transformative agency of the young (Unesco, 2017).

The Framework to Futurize Science Education addresses these concerns by suggesting how science education can provide students with tools for connecting with, and finding agency within, their personal and global futures. Based on the results of six FEDORA part-studies on students' perceptions and European curricula, we present nine issues to be addressed in science education. Following the presentation of these issues, we propose a set of 14 recommendations to *futurize science education*.

The framework is the final deliverable of FEDORA Work Package 3 ("Futurizing science education"), addressing the following objectives:

- To investigate the current status of the role of future in science education as manifested in curricula, textbooks and other educational materials (GO1; SO4)
- To develop an analytical framework and methodology to study the young generations' futures thinking, with respect to their hope, trust, desire, visionary and proactive moods in this accelerated, multi-velocity, complex and uncertain society (GO1; GO4; SO4)
- To investigate and reach an in-depth understanding on how European 11-19 years old students perceive the future and how they see the role of science and technology in their personal future, in societal changes and in global futures (GO3; SO4)
- To analyse the "time misalignment" and the need to futurize science education, and to suggest solutions to that end (GO3; SO4; SO5)
- To elaborate design criteria for examples of future-oriented activities aimed to develop future-scaffolding skills needed to grapple with the society of uncertainty in a responsible, sustainable way (GO3; SO4; SO6).

Based on the results of the work done in WP3, we now present an overview of the framework (Section 2), followed by a description of our analytical research approach and the part-studies (Section 3). Finally, we present a detailed description of the issues (Section 4) and recommendations (Section 5). Finally, we end with a brief discussion of the framework (Section 6).

2. Overview of the framework

The main part of our framework consists of 9 issues and 14 recommendations. Within this document, an “issue” denotes an aspect of (typical) science education or (typical) young people’s thinking that could be more deeply addressed. A “recommendation” denotes an aim, a method or an action that should be adopted or taken to address said issues.

2.1 Overview of the issues addressed

The nine issues are divided into three categories. Firstly, from our studies it emerged that young people feel themselves distressed when trying to imagine their future, or their futures thinking seems restricted in some way. They tend to feel powerless in front of the complexity of the “whole” future, or it seems singular and predetermined. Moreover, to manage this tough feeling, they close themselves into their rituals, or imagine themselves separate from the rest of the world. This category of issues is called *Powerless, detached or polarization-oriented young people.*

Secondly, looking at the role of science and technology in students' future narratives, we also found the tendency to separate what science and technology can do in the future for personal daily life and for societal issues. Students seem to employ multiple, even contradictory roles or discourses of scientific progress or sociotechnical change, such as science fiction imagery, hopes of simple tech-fix for sustainability, and uneasiness and uncertainty with change. Crucially, students struggle with understanding or integrating in their futures thinking the issue of who will act on these changes (i.e. the future). There are also critical issues in imagining how a technological and scientific change can happen, which is often seen as a linear continuation of the present towards the future, instead of contemplating possible radical or even paradigmatic revolutions. These issues are grouped under the category *Issues in young people’s views of science and technology.*

Finally, we note that, partly to address the issues listed above, the inclusion of future thinking education in science education is already in progress. However, there are still issues both related to the curricula design and educational integration, as the inclusion of futures perspectives is somewhat novel. As the purpose of this document is to guide this futurization process, we also address issues related to educational design and school culture. These recommendations form the category *Issues related to educational design and students future skills.*

The full list of the issues addressed in this framework is the following.

Powerless, detached or polarization-oriented young people

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect

Issues in young people's views of science and technology

- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future

Issues related to educational design and students' metacognitive skills

- Lack of explicit futures concepts and elements in curricula
- Challenges in diversity responsiveness and inclusion when discussing futures within education
- Lack of metacognition in futures thinking

The issues are more individually defined and explored in Section 4.

2.2 Overview of recommendations to futurize science education

To respond to these issues, we suggest *futurizing science education*, by enacting the 14 recommendations. We present each recommendation here briefly, and in Section 5 in depth. In this section we wish to highlight the target areas to which the recommendations apply, while in Section 5 we root the recommendations in empirical evidence and key theoretical concepts. Thus, this section also functions as a summary of executive action based on the recommendations.

The recommendations stem from points of convergence in responses to the issues listed above as well as insights in earlier research and theoretical work on future-oriented (science) pedagogy. Consequently, this framework is intended for "futurizing science education" in the sense that it gives actionable recommendations towards applying contemporary ideas in future-oriented education for resolving the issues identified in our part-studies. As reflected in *Fig. 1*, the recommendations relate to the issues in multiple ways. For this reason, this Framework calls for a comprehensive reevaluation-revision process to futurize science education.

We have grouped the recommendations into three categories. The categories indicate the general type of recommendation (aims, content, method) as well as the actors and institutions the recommendation is primarily aimed for.

WHY, FOR WHOM? General aims for science education

These recommendations relate primarily to the need to realign the aims of science education with the need to provide future-related capacities in a rapidly transforming world, and the actions to be taken and perspectives to be considered on a broad, overarching level. They are primarily intended for **policy makers**, **curriculum developers** and **teacher educators**.

I – Use futures thinking to cross, connect and contextualise 21st century skills

II – Incorporate future concepts and elements in science curricula

III – Incorporate futures thinking in science teacher education programs

IV – Understand and address the personal, gendered, cultural, religious, socioeconomic and political dimensions of futures thinking and related beliefs

V – Foster the development of future-scaffolding skills

WHAT? Contexts and contents of science education

These recommendations relate to the need to reevaluate the contents of science teaching and learning alongside the contexts that science learning content is framed in. Thus, while the previous category relates to high-level examination of what is valued as a goal in science education, this second category emphasises typical curricular content and pedagogical focus points. These recommendations are primarily intended for **local level curriculum developers**, **teachers**, **teaching material developers** and **teacher educators**.

VI – Elicit students' scientific and technological images of the future

VII – Address ongoing and emerging trends in science and technology

VIII – Highlight the role of human agency in the development of science and technology and in sociotechnical change

IX – Address and embrace complexity and uncertainty

HOW? Pedagogical methods in science education

These recommendations relate especially to teaching practice, school culture and classroom activities and discussion. They are intended to be seen as especially relevant for **teachers**, **teaching material developers** and **teacher educators**.

X – Embrace emerging teaching using interdisciplinary projects

XI – Practise different types of futures thinking

XII – Deconstruct spacetime rituals in science classrooms

XIII – Guide the students to manage tensions and overcome polarizations

XIV – Use collective group work to open up to alternative futures

The issues and recommendations and their interconnections are summarised in *Figure 1*.

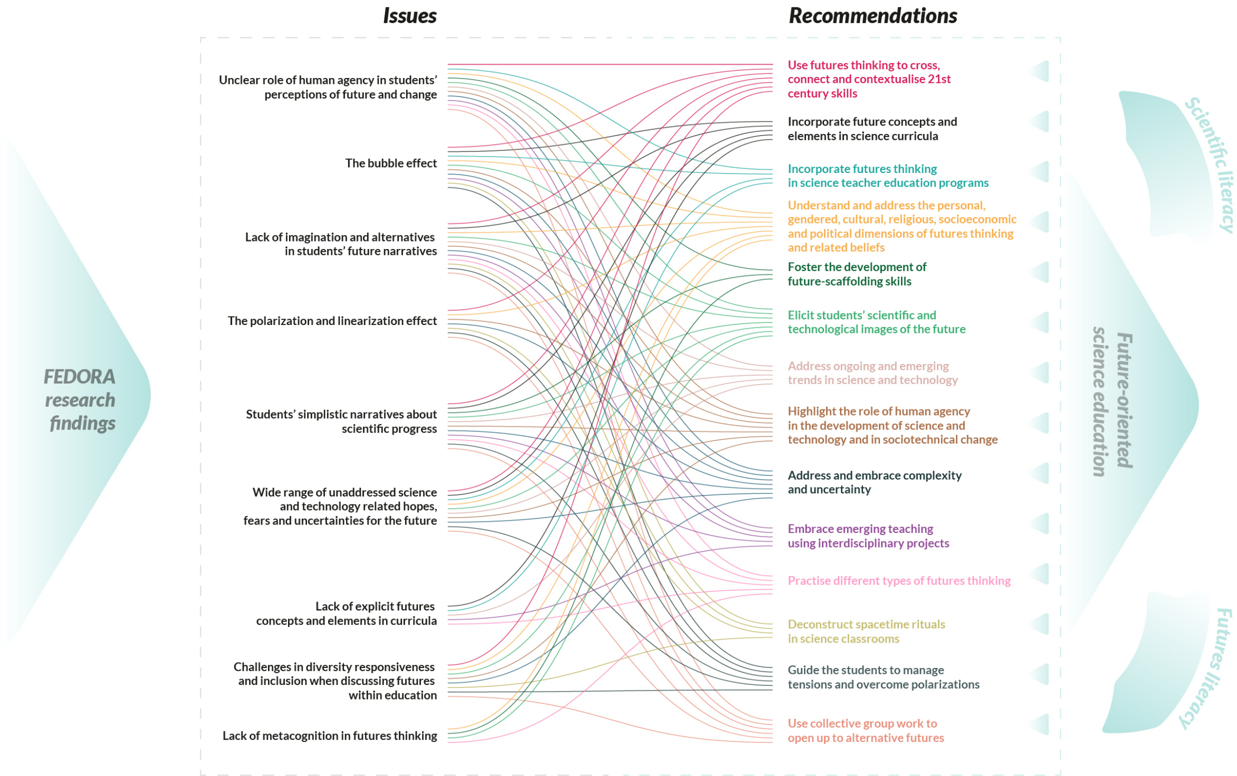

Fig. 1. A visualisation of the Framework to Futurize Science Education. The issues arising from the part-studies connect in complex ways with the 14 recommendations; each recommendation addresses multiple issues. The recommendations contribute to futurizing science education, framed by the aims of scientific literacy and futures literacy.

As *Figure 1* incidates, this framework presents the issues arising from the research findings of FEDORA part-studies, our fourteen recommendations to futurize science education, and how the recommendations connect with the issues. While the recommendations are responses to the issues, they are also contextualised applications of future-oriented science pedagogy, which takes its departure from research in science education (such as conceptualisations of scientific literacy) and futures thinking and futures education (such as futures literacy). Furthermore, the recommendations also feed into future-oriented science education, highlighting matters that require further theoretical integration. For this purpose, a peer-reviewed research paper on the framework is in progress; this paper will more deeply address the theoretical underpinnings of the framework and the theoretical implications of the issues and recommendations.

3. Background: FEDORA part-studies

3.1 Overview of the part-studies

The recommendations presented in this document stem to a large extent from issues identified in research carried out within the FEDORA project. Namely, we draw from six part-studies, all of which have been or will be more extensively reported elsewhere. Here we present a brief overview of the research in general, followed by a similarly brief overview of each part-study.

For research on students' perceptions of the future, a general analytical and methodological framework was developed by FEDORA partners to guide the alignment of the part-studies. However, each study employs its own methodology according to the specific point of interest. The part-studies focus on the following aspects:

Part-study 1: Finnish students' images of technological futures and perceptions of sociotechnical change

Part-study 2: Italian students' perceptions of the future

Part-study 3: Types of futures thinking in Finnish upper-secondary students' images of the future

Part-study 4: KinderTrendrede: Dutch children's and youth's collective futures views of their city

Part-study 5: Desk research on Futures with a focus on Futures Consciousness elements in Finnish, Italian, English, Lithuanian and Dutch secondary level curricula

Part-study 6: Italian upper-secondary students developing future-scaffolding skills through a future-oriented module on computational simulations

The analytical framework draws on some earlier initiatives to adapt futures thinking in science education (Branchetti et al., 2018; Carter & Smith, 2003; Jones et al., 2012; Levrini et al., 2021; Paige & Lloyd, 2016). Our approach interconnects earlier research on people's perceptions carried out in a variety of domains: futures studies, youth studies, science and technology studies, and educational studies on agency, as well as societally oriented approaches to science education, such as the SSI (socioscientific issues) and STSE (science, technology, society, environment) movements.

The analytical framework draws from the extant research analysing young people's perceptions on the future. For example, in the literature, "two-track thinking" has been a typical finding: personal futures may be seen as positive and in one's own hands, but the national and especially the global futures as gloomy and out of one's influence (e.g. Cook, 2016; Rubin, 2013). Research in the field of futures studies has also shown how positive images of the future and a perspective of hope connect to seeing new possibilities, while focusing on threats and negative images of the future narrows down thinking (e.g. Lombardo, 2016; Rubin, 2013). Thereby, futures thinking is intertwined with the concept of agency (see e.g. Cuzzocrea & Mandich, 2016; Mangnus, 2021; Poli, 2021). Agency has been widely promoted as an educational objective, both generally (Unesco, 2017) and specifically to science education (European Commission, 2015). In social science, agency is commonly defined as the capacity for autonomous social action during which people intentionally transform their social and material worlds (Biesta & Tedder, 2007), and it is also at the centre of futures thinking (e.g. Ahvenharju et al., 2018).

Science and technology has a central role in such structures (Angheloiu et al., 2020). In parallel, research has shown that science and technology connect to young people's fears and deterministic future views (Carter & Smith, 2003), and also to their hopes about sustainable futures (Cook, 2016). Both deterministic and constructivist views of technology (Bauchspies et al., 2006) can be recognised in students' future thinking, deeply influencing their sense of future and agency and, thereby, having important implications for future-oriented science education.

Taking departure from these theoretical considerations, the analytical framework aims for a dynamic, integrated understanding of interrelationships between young people's future perceptions, agentic orientations and the roles of science and technology in them. This understanding is pursued by employing an approach informed by phenomenography (Marton, 2015) to describe and interpret young people's forms of thought (or categories of description) about the domains depicted in *Figure 2*.

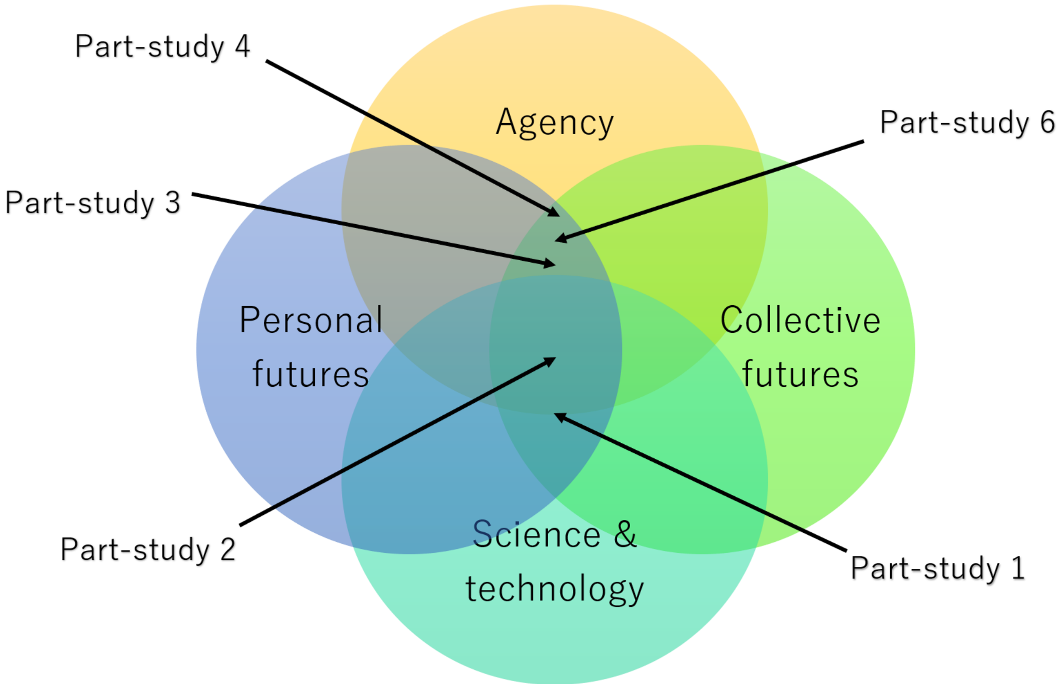

Fig. 2. The domains of students' perceptions under investigation: personal and societal/global ('collective') futures, agency, and science & technology. The research carried out in FEDORA, consisting of four part-studies, focuses especially on the interrelations (overlaps) between these domains. The Desk research (Part-study 5) utilises a different analytical framework, as it does not deal with young people's perceptions.

The data for part-studies consist of students' writings on the future. Similar methodological approaches of narrative inquiry have previously been used e.g. in research on youth's agency (e.g. Cuzzocrea & Mandich, 2016) and views of the future (Angheloiu et al., 2020).

The core of the data on students' perceptions consists of data collected in Finland, Italy and the Netherlands within the projects I SEE (iseeproject.eu) and KinderTrendrede (kindertrendrede.nl). While complementary data has been collected, it is not included in these analyses. The main corpus of data consists of 16-19 year old upper secondary school students' essays with the title "A typical summer day in 2040", collected in Finland and Italy in the context of the Erasmus+ project "I SEE". Also, additional data from the Netherlands is analysed to expand the research into younger, 8-14 years old children. A subset of European curricula, i.e. Finnish, Italian, English, Lithuanian and Dutch secondary level curricula were also selected for analysis (see *Part-study 5*).

3.2 Part-study 1: Finnish students' images of technological futures and perceptions of sociotechnological change

Reported at length in academic journals:

> Rasa, T., & Laherto, A. (2022). Young people's technological images of the future: implications for science and technology education. *European Journal of Futures Research*, 10(1), 1-15.
>
> Rasa T., Lavonen, J., & Laherto, A. (2022). Agency and transformative potential of technology in students' images of the future: Futures thinking as critical scientific literacy. *Manuscript submitted for publication.*

The focus point of *Part-study 1* is the role of science and technology in students' images of the future. Consequently, the study is rooted strongly in Science and Technology Studies on one hand, and on studies on (young people's) perceptions of the future on the other. In the study, themes in students' writings about imagined (desirable) futures were analysed first inductively, revealing surface-level expectations and imaginations concerning technology and sociotechnical change, and then more deeply in regard to the nature and the role of human agency in such change.

Through qualitative content analysis, we examined a set of 58 Finnish upper secondary school students' essays ("A typical summer day in 2040") that describe desirable future worlds. These essays were collected before a learning intervention. We analysed, at a sentence level, what technologies are present in these essays, what aspects of the world and human life are affected by technology, whether these effects are framed as positive, negative, or in neutral or conflicted terms, whether sociotechnical changes were framed as value-laden or value-neutral, whether these changes were incremental or radical, and how agency in sociotechnical change was discussed.

Technologies depicted in students' images of the future consisted to a large extent of everyday devices, technological systems and broad categories of technology (e.g. vague 'technology', energy production systems, large-scale automation of service jobs). Technology was usually seen as affecting everyday convenience (often specifically household activities), the structure of job markets and environmental issues. Technology was also associated with social life, equality, health and privacy, or connected with larger issues such as overtechnologisation of human life or general societal progress.

Certain technologies were associated with more worries and fears. These included automation, digitalisation and entertainment technology. Most negative sociotechnical change was seen in increasing passivity, unstable job markets and greater cybersecurity concerns. Meanwhile, the impact of technology on the environment was discussed in overwhelmingly positive terms. Indeed, technology was given various highly different roles in transforming our world: building sustainability, saving time from mundane tasks, accelerating inequality, making jobs obsolete, reducing privacy and providing interesting career opportunities.

Some students saw more transformative potential in technological development, while some expected only incremental, or almost static expectations. Sociotechnical changes were often discussed in unproblematised or even deterministic terms. Problematised or socioconstructivistic views of technological change were also identified, especially when discussing larger developments in technology in general, artificial intelligence, or automation. Agency was discussed somewhat vaguely, although some students clearly attributed sociotechnical agency to institutions, technology experts, or themselves.

3.3 Part-study 2: Italian students' perceptions of the future

Reported at length in academic journals:

> Barelli E., Tasquier G., Caramaschi M., Satanassi S., Fantini P., Branchetti L., Levrini O. (2022). Making sense of youth futures narratives: Recognition of emerging tensions in students' imagination of the future. *Front. Educ.* 7:911052. doi: 10.3389/feduc.2022.911052

Tasquier, G., Knain, E., Jornet, A. (2022). Scientific Literacies for Change Making: Equipping the Young to Tackle Current Societal Challenges. *Front. Educ.* 7:689329. doi: 10.3389/feduc.2022.689329.

Part-study 2 aims to point out students' perceptions about their future perceptions, in their relation to science, technology and agency. Our previous studies made methodological issues emerge about the effectiveness of the tools we used to collect the data, and the significance of our results. On the basis of these preliminary results we set out to analyse a) Are the themes we observed in the previous studies (Levrini et al. 2019, 2021) effective to give back a faithful picture of the information contained in the data? What sub-themes can be observed? b) What useful and interesting knowledge does their application on data generate? c) What investigation tool can be developed to collect better data to interpret our "polarization and bubble effects"?

The dataset consisted of almost 220 essays written by students, aged between 17 and 19 y.o, within the "I SEE" project.. Following a phenomenological thematic approach, the study was conducted through a bottom-up process: data was the most important source of information and the group applied methods of cross-checking to keep under control the projection on the data of a priori external big theories/visions. Many ideas and concepts resonated with some theoretical references that have been used at an interpretative level. They are the essay by Byung-chul Han (2021) titled "The palliative society" and the italian essay by Colamedici & Gancitano (2018) titled "Società della performance, come uscire dalla caverna" (the performance society). A subset of the essays was selected for analysis using a complex analytical grid that has been reported elsewhere (see published research).

As for the polarization attitude, several studies have shown that the students, in front of very demanding socio-scientific issues, tend to make the dynamics between the individual and collective dimension collapse into its extremes: they tend to either focus on very concrete, personal and individual actions (challenges) or to see the issues so big that only political, collective and top-down actions can make the difference. This dichotomy is another manifestation of the "two-track thinking" and can emerge in many ways and in many aspects, such as the values, interests but also in the types of social relations that students consider (Levrini et al., 2021). Being the dichotomy a possible key to interpret agency and the sense of change, we thought it deserved further investigation.

As for the “bubble effect”, we observed that the pandemic situation emphasized both the relevance of daily-life and school rituals as ways to manage anxiety toward the future and the tendency to search for comfort zones through the activation of special personal and social routines and rituals that “close the systems” (Levrini et al., 2021).

This phenomenon led us to point out some focal themes that attracted our attention and became central issues of this part-study: the dynamics between individual and collective and the eventual polarization; the rituals; the emotions that accompany thinking, actions or imagination.

3.4 Part-study 3: Types of futures thinking in Finnish upper-secondary students' images of the future

Peer-reviewed research is in preparation.

Part-study 3 analysed how upper secondary school students write about the future and how students' futures thinking can be conceptually connected to their agentic orientations towards the future. Thereby, in the analytical framework (see *Fig. 2*) this study is located in the intersection of the domains of agency and futures perceptions.

Theoretically, this part-study builds on two domains: the ecological model of agency developed in sociology and educational science, and the typologies describing how people think about the future developed in the field of futures studies. According to the seminal work on agency by Emirbayer and Mische (1998), individuals' agency in relation to structural contexts is profoundly dependent on how they orient towards the past, the future and the present in different situations and moments of time. In the field of futures studies, a typical approach to analyse futures thinking is that scenarios, or images of the future, can be created from various orientations (see e.g. Bishop et al., 2007; Börjeson et al., 2006). The first type of orientation discusses what the future is likely to be (probable futures), while the two other types of futures thinking concern what the future could be (possible futures), and what it should be (preferable futures).

Building on these ideas, *Part-study 3* set out to address the following research questions: 1) How do the different types of futures thinking manifest in students' essays on the future? 2) What is the prevalence of different types of futures thinking in students' essays on the future 3) How do the types of futures thinking connect to the temporal dimensions of agency?

The data consisted of 58 pre-intervention essays collected from 16-19 year old high school students in Helsinki. The students were assigned to write up an essay with the title "A typical summer day in 2035/2040". The qualitative content analysis of the students' essays took departure from the three above-discussed orientations of futures thinking. Thereby, the analysis was primarily deductive, but included also an inductive component (cf. Braun & Clarke, 2006). The process went back and forth between refining the category descriptions and coding the students' passages. The analysis paid attention to both the content and the form of students' expressions, and the role of the self in the narratives.

The analysis resulted in three categories of "future talk", each representing a different type of futures thinking as manifested in the essays: In the first type, "Stability / extrapolation", students described the future either as very similar to the present or by extrapolating the current trends so that the future is a linear continuation of the present. Typical expressions of this type of future talk were 'still is', 'has remained/stayed', 'similar to the present', 'has improved', 'has developed', 'are a bit better', etc. The second type, titled "Alternative futures", shows a conception of the plurality or conditionality of futures, questions assumptions and/or attempts to come up with novel and creative alternatives to the current trends. Typical expressions in this type of futures talk are "if, then…", "may be", "may change", "on the other hand", "for example", "possibly" and "depending on". Type 3, titled "Preferable futures", takes departure from students' own hopes, desires and dreams. This kind of futures talk is value-laden and in that sense personal. Often this type of futures talk starts from a desirable future of unlimited possibilities. Sometimes the type 3 of futures talk included explicit expressions like "I wish", "I hope" and "I dream of", but more often such thinking was implicit in the essays.

In most essays, it was easy to identify a single primary type of future talk. Half of the essays had also a secondary type of future talk. No essays had a significant amount of more than two types of futures talk. These types of futures talk can, with the theoretical framework, be connected to reproductive and transformative types of agency.

3.5 Part-study 4: KinderTrendrede: Dutch children's and youth's collective futures views of their city

Peer-reviewed research is in preparation.

Part-study 4 builds mainly on two domains: the five dimensions of Future Consciousness (Ahvenharju, Minkkinen, & Lalot, 2018) and the typologies describing how people think about the future, both of these developed in the field of futures studies (see e.g. Bishop et al., 2007; Börjeson et al., 2006; Hicks & Holden, 1995; Voros, 2003).

Futures consciousness is a capacity and the five dimensions show the prior conditions that allow future-oriented thinking and behaviour to take place. The 5 dimensions are (following Ahvenharju, Minkkinen, & Lalot, 2018):

Time perspective: being aware of tomorrow and of the way that events and their consequences follow each other over time: understanding past, present and future.
Agency beliefs: a sense of being able to influence the future through individual or collective agency.
Openness to alternatives: the capability of embracing and appreciating change; questioning established truths; creativity, imagination, critical thinking and openness.
Systems perception: holistic thinking, understanding complexities and complex casualties, long-term thinking.
Concern for others: the capacity for committing oneself to bettering not only one's own future, but the future of others, of society, and even the future of generations; ethical reflection.

In this part-study we analysed collective group essays written by young people, collected from two Dutch cities over several years. Through qualitative content analysis (combining inductive and deductive coding), we analysed the manifestations and connections between firstly the dimensions of futures consciousness, and secondly the future types (probable, plausible, possible, preferable) present in the essays, and the general future outlook of the participants. These essays were collected within KinderTrendrede, a yearly recurring futures project where youngsters aged 8 to 14 years old write a future essay as a group and present this to their municipality as a way to provide advice on the future of their city.

In the study, a set of dominant aspects was identified. The most dominant aspects that emerged from the essays were *living together*, *preferred futures*, *agency beliefs* and *concern for others*. The competences most used when discussing the future e.g. agency, preferred futures, alternatives and critical perspectives, but rarely systemic perspectives or technology. Technology was associated with mixed feelings ranging from hope to worry. However, typically the essays related to hope.

3.6 Part-study 5: Desk research on Futures with a focus on Futures Consciousness elements in Finnish, Italian, English, Lithuanian and Dutch secondary level curricula

Peer-reviewed research is in preparation.

This study focused on investigating the current status of the role of future in science education as manifested in curricula. Theoretically, it was mainly based on two domains: the five dimensions of Future Consciousness and the direct or indirect usage of futures thinking terminology.

The 5 dimensions of Futures Consciousness (Ahvenharju, Minkkinen, & Lalot, 2018) are agency beliefs, systems perception, openness to alternatives, concern for others, time perspective). A summary of these dimensions can be found in Section 3.5 above.

The direct or indirect usage of futures thinking terminology was utilised as a proxy to investigate if aspects of futures thinking are directly mentioned or indirectly touched on within the curricula. Furthermore, they were taken as opportunities that could provide a gateway to relate curricular content to futures thinking. Here, direct elements are closely related to futures thinking using explicit terminology such as time horizons, forecasting, anticipating, predicting, etc. Indirect elements are more broadly used and implicit, which offer opportunities for futures thinking to relate to, for example: change, imagination, creativity, agency, uncertainty, critical thinking, experimenting, and questioning.

We chose to focus on desk research of the curriculum of lower secondary education and the age group of students that are 11-15 years old. This selection has less fragmentation with regards to chosen specializations as students of this age group are receiving more general (science) education in the lower secondary stream. Furthermore, for this age range, the selected curricula are more comparable.

Through qualitative content analysis (combining inductive and deductive coding) we analysed the curricula on the dimensions of Futures Consciousness, direct or indirect usage of futures thinking terminology, science content, and real-life and concrete current topics that may tie into futures thinking, such as climate change, polarisation, biotechnology, etc.

The results, which will be more fully reported elsewhere, show that there are not many direct mentions of futures thinking concepts in the general curricula or the subjects' descriptions. Although all national curricula state that education has to prepare and develop students for their further lifetime, they do not always use specific futures terminology for this. Examples of sections that related directly used words like 'anticipate', 'planning', 'long-term' and 'innovative answers'. Notably, the Finnish curricula was found to discuss value-based technology decisions for a sustainable future and broadening students' horizons to include e.g. transgenerational thinking. Thus, the analysis revealed explicit futures content in curricula, opportunities for the inclusion of futures themes, and potential oversights in this regard.

3.7 Part-study 6: Italian upper-secondary students developing future-scaffolding skills through a future-oriented module on computational simulations

Reported at length in academic journals and in a doctoral dissertation:

Barelli, E. (2022a). *Complex systems simulations to develop agency and citizenship skills through science education.* Doctoral dissertation. http://amsdottorato.unibo.it/10146/

Barelli, E. (2022b). Imagining the school of the future through computational simulations: Scenarios' sustainability and agency as keywords. *Frontiers in Education*, 7. https://doi.org/10.3389/feduc.2022.897582

Barelli, E., & Levrini, O. (2022). Computational simulations at the interface of physics and society: a teaching-learning module for high school students. *Il Nuovo Cimento C*, 45(6). doi:10.1393/ncc/i2022-22213-6

Barelli, E., & Levrini, O. (in press). Navigating micro and macro levels of agent-based simulations to build analogies with real-world issues. *ESERA 2021 Electronic Proceedings.*

The focus point of *Part-study 6* is the role of future-oriented science education in fostering upper-secondary school students' development of future-scaffolding skills. Being the research based on the analysis of future scenarios that the students developed for issues that were important both on an individual and a societal level, this part-study is rooted on the studies on personal and collective futures, as well as on agency.

In 2021, 16-18 y.o. Italian students engaged with the future-oriented activities of a module on simulations of complex systems. After having been taught about the conceptual features of simulations, the students carried out an activity of scenario building on the basis of the simulation artifact, identifying probable, possible, and desirable futures for a topic of their interest. At the end of the course, some students were interviewed.

The dataset obtained in the implementation was analysed in search for markers that indicated students' development of so-called future-scaffolding skills that the literature in future-oriented science education had previously pointed out (Levrini et al., 2021; Tasquier et al., 2019). Qualitative analysis was carried out to point out whether the students developed future-scaffolding skills throughout the activities and how: i) they put them into play in their final presentations and ii) they talked about their learning experience in the module in terms of future-scaffolding skills development.

The analysis revealed a clear misalignment between the skills exhibited by the students during the presentation of their work in the future-oriented activity and the self-reported ones. If we consider the relative frequencies, in the final presentations were detected much more structural than dynamical skills (skills into action), while in the interviews the students gave slightly more emphasis to the development of dynamical than structural skills (verbalised skills). The difference between the distribution of the two types of future-scaffolding skills is remarkable. If, with tailor-made designed activities, the students can be led to develop and exhibit structural skills, when we ask them to describe these competences, they seem to lack words to describe their achievement. This difference between the distribution of the two types of future-scaffolding skills deserves further analysis.

Another result achieved through this part-study was an improved operationalisation of the future-scaffolding skills. This was not only helpful to recognise the skills in students' actions/presentations/tasks and in their way of talking about their engagement with the module, but was also a way to orient the design of specific teaching-learning activities based on the reconstruction of the disciplinary contents to teach. In this specific part-study, this work was done with agent-based simulations that were presented to the students for their conceptual and epistemological thickness in a way that could support the development both of structural and dynamical skills.

4. Issues addressed by this framework

In this section, we present the issues identified within the part-studies. The issues provide nine entry points into matters in education that this framework addresses. As outlined in Section 2, the issues are divided into three thematic categories: *Powerless, detached or polarization-oriented young people*, *Issues in young people's views of science and technology*, and *Issues related to educational design and students future skills*. We present the issues by category, following the order given in *Fig. 1*. For each issue, we give a brief description, outline the empirical basis, and point the reader to some further material.

4.1 Powerless, detached or polarization-oriented young people

Unclear role of human agency in students' perceptions of future and change

What's the issue?

Students' conceptions of the future may be static, deterministic or powerless. In other words, images of the future may lack imagination and change, or they may be limited by unquestioned assumptions (e.g. about technological progress). Both bleak and optimistic images of the future can also downplay opportunities for human agency. For example, students may feel powerless about influencing the ongoing sustainability crises.

The unclarity of agency in students' futures thinking implies that they are not sure who has influence over things that matter to them. On the other hand, it seems that engaging with futures thinking may elicit students' beliefs about agency, allowing for discussion about agency: when the future is seen as different from the present and not predetermined (i.e. the world is seen as a process), agency becomes more clear.

Empirical basis

In *Part-study 1*, students' writings about the future were found to discuss agency mainly implicitly and vaguely. Typically, efforts to shift towards more sustainable or value-aligned societal systems were attributed to "people". While some students were able to identify and address the roles of e.g. policymakers, scientists and citizens, or even themselves, many students saw the future as shaped by vague and even deterministic “trends” rather than meaningful choices.

In *Part-study 2*, students described a broad presence of science and technology in their future. The application of personal-societal dichotomy on their thinking around science and technology has involves a sense that a generic “technology” will solve environmental or social issues, without giving a concrete image of who will have acted to trigger that change.

Similarly, in *Part-study 3*, students were found to struggle with thinking about desirable futures and change-making, focusing more on e.g. extrapolation of current trends.

On the other hand, in *Part-study 4*, where young people discussed possible futures together in a shared activity, their imaginative discussion grew energized, and a positive outlook was found as their sense of agency increased.

Further reading

Article based on *Part-study 1*: Rasa, Lavonen, & Laherto (2022).
Young people’s conceptions of agency: see e.g. Angheloiu, et al. (2020)
Lack of human agency in shaping the future: see e.g. Special Eurobarometer 419 (European Commission, 2014)
Connections between agency and futures literacy: see e.g. Miller (2007); Poli (2021); Rasa, Palmgren, & Laherto (2022); see also Facer (2012)
The role of collective activity in imagining futures, and increases in perceived agency in groups: Rasa, Palmgren, & Laherto (2022)

The bubble effect

What’s the issue?

The pandemic unveiled and emphasised some daily-life and school rituals/habits that students enact to manage anxiety toward the future as well as to manage the tendency to search for comfort zones. These personal and social routines and rituals tend to “close the systems”, by creating boundaries between what can and what cannot be kept under control. These rituals and habits appeared to be particularly evident during the pandemics, when the students needed to manage, emotionally, the high level of novelty and uncertainty of that time. This “bubble effect” manifests in a deep detachment between the personal and the social sense of change, agency and directionality.

The rules and paces that characterise daily-life personal rituals/habits position the young in the role of agents and some of them use science and mathematical practices to build and stay in their own space-time bubble, protected from society. The social directionality, even when it is perceived or recognised, is far from their agency.

The students tend to manifest a strong, urgent and authentic need to immerse themselves in deep personal experiences but, in several cases, this need is completely detached from what the school offers or requires them to do.
This mismatch between the personal and the social dimensions creates isolation and limits the young’s agency.

The bubble effect can be used to elaborate on the dichotomy between *alienation from time* (that leads to a sense of identity fragmentation) and *time re-appropriation* (that leads to fostering the capacity to align different parts that characterise the multifaceted nature of identity). The bubble effect, indeed, seems a manifestation of the need to re-appropriate their one time, in an era where “time is out of joint”, as Hamlet would say.

Empirical basis

In *Part-study 2*, the bubble effect emerged in some students' essays about an ideal future day in 2040, in which they described a daily-routine centred on their own affairs, in which all daily tasks were neatly scheduled. The bubble effect in this study is highlighted into the dichotomy between personal and societal when it is observed a description fully focused on the personal issues and needs.

Further reading

Study on students’ school rituals and habits during pandemic time: Levrini, et al (2021a).
Alienation from time and acceleration: Rosa (2010).

Lack of imagination and alternatives in students' future narratives

What's the issue?

While students' are able to actively imagine futures, they may have limited skills and experience in imagining discontinuities, completely new avenues of research, or amplification of current "weak signals". For example, they may lack understanding of current open questions in scientific domains and the possibilities relating to societal change over time, and may thus imagine futures that are primarily extrapolations of the present. Furthermore, students need practice to be able to imagine futures based on values, dreams and choices; this type of thinking ("preferable futures") is needed to activate the projective dimension of agency. The shortage of such thinking is not specific to students or the young, but has been observed among teachers and other adults as well.

Students may have weak competences in futures thinking especially at longer timescales where discontinuities are increasingly likely. They may not see potential for breakthroughs, paradigm shifts, novel innovations or new risks. Furthermore, they may not perceive scientific knowledge as bounded in a way that reflects current scientific thinking.

The difficulty to deeply imagine futures is also related to the differences between individual and collective capacities: one student is more likely to come up with a few detached ideas, while a group may be more capable of weighing ideas against each other and even coming up with a plurality of possible futures.

Empirical basis

In *Part-study 1*, students' images of technological futures were often limited to typical science fiction staples, with few technologies or ideas that are not highly prevalent in today's society.

In *Part-Studies 3* and *4*, students' futures thinking skills and tendencies were found to mostly relate to extrapolation rather than "what-if" thinking or visioning a preferable future.

In a separate study (see Varpanen et al., 2022) we have also observed similar patterns among in-service teachers.

In *Part-study 4*, younger students were found to reach rather complex future-related ideas by working in groups of 5 to 7.

In *Part-study 2*, the analysis of students' essays also revealed a "certain-uncertain" dichotomy. In some case, students' narratives were polarised with regard to certainty: a strong need of the young people for control emerged, manifested in the almost perfectly scheduled daily commitments, and in knowing with certainty which job or lifestyle they will live without any plan B. In other cases, the students' essays displayed a degree of uncertainty about how exactly their life and future society will turn out, considering various possibilities instead of an only one evolution.

Further reading

Articles based on *Part-study 1*: Rasa, Lavonen & Laherto (2022); Rasa & Laherto (2022)

Analysing teachers' futures thinking (with a same kind of methodology that is used in *Part-study 3*): Varpanen et al. (2022)

Lack of imagination: Angheloiu et al. (2020)

Present expectations and futures thinking: Borup et al. (2006)

The concept of futures literacy, e.g. Miller (2015)

The polarization and linearization effect

What's the issue?

We see on the basis of the literature the tendency to reduce the complexity of a problematic issue and polarize positioning in dealing with it is a typical phenomenon induced or alimented by social media.

In education the "polarization attitude" mainly manifests when students, in dealing with SSI, tend to reduce the dynamics between the individual and collective dimension to its extremes, either a mere personal/individual issue or a social/big issue.

As for the future, polarization is evident in the phenomenon called 'two-track thinking'. It refers to a typical finding: personal futures may be seen as positive and in one's own hands, but the national and especially the global futures as gloomy and out of one's influence. Research in the field of futures studies has also shown how positive images of the future and a perspective of hope connect to seeing new possibilities, while focusing on threats and negative images of the future narrows down thinking. Two-track thinking manifests itself in several types of polarisation (between individual and collective dimension, between career-orientation and societal-orientation…) and can lead to the creation of "safe bubbles" where the young feel to have the control of any action.

Empirical basis

In *Part-study 2*, operational lenses to recognise/observe/study/characterise the polarisation phenomenon have been elaborated. The results of these students' essays analysis led to the definition of both "polarization" and "complexification" attitudes that represent the ways in which students' narratives are positioned with respect to possible dichotomies that appear in students' imagination of future.

In *Part-study 4* this became clear as well when young people elaborated on their ideas of the future together. They indicated different perspectives according to their belief (sometimes even copying what they heard from their parents or teachers).

Further reading

Tendency to reduce complexity / polarize one's position: Baldassarri & Page (2021); Del Vicario et al. (2016).
Two-track thinking: Cook (2016); Rubin (2013).
Young people's safe bubbles: Levrini et al. (2021a).
Positive images related to seeing new possibilities versus negative images related to restricting thinking: Lombardo (2016); Rubin (2013).
Articles based on *Part-study 2*: Barelli et al. (2022); Tasquier, Knain, & Jornet (2022).

4.2 Issues in young people's views of science and technology

Students' simplistic narratives about scientific progress

What's the issue?

Science and technology may have a fantastic, utopic role in students' images of the future. This is exemplified by narratives where science solves "all problems" within the students' lifetime, or provides a once-for-all technological fix for sustainability crises.

However, some students are also able to construct more complex, systemic narratives about (certain) socioscientific issues. For example, students can imagine futures where biotechnological development is carefully regulated, cities where technology is "balanced with nature", and states which maintain and ensure web privacy and security in the midst of further digitalisation. Even more typically, students may be able to construct future narratives where socioscientific issues have pros and cons and thus require some societal deliberation; for example, automation and digitalisation can be generally positive developments, but still cause unemployment, alienation and economic inequality that needs to be addressed by societal means. However, these systemic or multifaceted perspectives are not typical; instead, future narratives may be simplistic, falling back on superficial "future-markers" such as flying vehicles, glossy architecture and vague "robots".

On a broader level, this issue is a case of the lack of wider and more rigorous systems perspectives in students' futures thinking, i.e. that lack of connecting changes in one area to changes in another.

Empirical basis

In *Part-study 1*, students' images of desirable technological futures were found to discuss the sociotechnical landscape of the future mainly as one that facilitates carefree everyday life, linearly solves societal issues, or alienates people from each other and the natural world in a somewhat inevitable manner. However, ca. 20% of students' discussions of technology did question the linear, unproblematic development of technology into a desirable direction (or, on the other hand, dystopic trajectories) and called attention to the complexity of sociotechnical change.

In *Part-study 4*, similarly mostly technology for facilitating daily life was discussed, and in fact for some participants technology was not very prevalent in their futures thinking. Furthermore, mostly all the topics we discussed were seen as stand alone topics. There were no direct links made between for instance discussions we had about nature and the effects of housing and mobility on nature.

Further reading

Articles based on *Part-study 1*: Rasa, Lavonen & Laherto (2022); Rasa & Laherto (2022)

Hopes of “technological fix”: see e.g. Cook (2016); types of young people’s future narratives: see e.g. Angheloiu, et al. (2020)

Systemic thinking as a dimension of futures consciousness: Ahvenharju et al. (2018)

Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future

What’s the issue?

Students seem to be aware of the role science and technology has had for the formation of society. They also seem to have capacities to imagine futures that are, at least in some ways, different from the present, and advances in science and technology are often discussed as the cause of such change.

Science and technology may take various, even contradicting roles in students’ futures thinking. Typically the most central roles are that of facilitating manageable everyday life, and building more sustainable societies. Other roles may include huge leaps in prosperity as well as creation of dystopic societies (e.g. surveillance states, alienation amidst intelligent robots). For students, the idea of technological change may also relate to uncertainty: if radical changes are seen as unpredictable “Faustian bargains”, the future may seem like a coin-toss. The uncertainty and unpredictability of the future thus is a crucial issue to be discussed.

For students, some of these roles may connect more clearly to scientific literacy and school science content: for example, technology and sustainability may be seen as related. However, in some contexts the hopes and fears may be detached from the students’ knowledge, creating feelings of irrelevance and powerlessness. Crucially, the future-related hopes and fears students have can often be detached from curricular content, causing a lack of motivation as well as lower perception of knowledge and skill related agency.

Empirical basis

In *Part-study 1*, students' images of the future were found to discuss somewhat varied technological points of interest. From robots and automation to smart homes and transportation; from green energy to inequality and isolation; from issues in privacy and cybersecurity to seeing technology as a source and sign of human progress, students' were found to be able to imagine worlds with various technologies and impacts of technology, even if their imaginations were somewhat limited to everyday gadgets. Similarly, in *Part-study 4*, students had mixed feelings about the role of technology in their future lives, which led into some ethical discussions. In *Part-study 2*, technology was related strongly to personal well-being, especially as a tool for domestic and daily life.

Further reading

Articles based on *Part-study 1*: Rasa & Laherto (2022); Rasa, Lavonen & Laherto (2022).

Studies on people's (technological) futures perceptions: see e.g. Angheloiu et al., (2020); Cook (2016); Heikkilä et al. (2017); Kaboli & Tapio (2018); van der Duin et al., (2020); see also Special Eurobarometer 419 (European Commission, 2014)

4.3 Issues related to educational design and students' metacognitive skills

Lack of explicit futures concepts and elements in curricula

What's the issue?

"Young people go to school to prepare for the future"; this type of statement is mentioned in introductory parts of most of the curricula. You would therefore expect that future terminology would be present in the description of curricula.

The opposite is true. There are hardly any direct links made to the future and also indirectly, if already there, the connections to futures concepts are hard to make when you don't have a futures-mindset.

This means it is not evident for teachers, as they are usually not trained in teaching the future, to discuss the future in their classroom.

And if already interested in teaching the future, teachers have to feel comfortable enough to play with the future, deal with the uncertainty, use their imagination and not to be afraid to not know the answer.

Empirical basis

The desk research (*Part-study 5*) shows that there are hardly any explicit mentions of the future in the secondary level of the Finish, Italian, English, Lithuanian and Dutch curricula. The most direct mentions have been spotted in the Finnish curriculum.

Indirect mentions of the future, like change, imagination, creativity, agency, uncertainty, critical thinking, experimenting and questioning are more broadly used, which offers opportunities to add future concepts in the different curricula.

The futures consciousness dimension systems thinking is mentioned a lot, especially in the science related curricula descriptions. But there seems to be a lack of the dimension of time perspective, the relation between the past, present and future, and agency beliefs, the idea that you have an influence on something.

Further reading

Cultivating teachers' beliefs, knowledge and skills for leading change in schools. Carrington e.a. (2010)
Ethical dilemmas: Teaching futures in school, Bateman (2015)
The five dimensions of FC, Ahvenharju et al (2018)
Individual futures consciousness, Ahvenharju et al (2021)

Challenges in diversity responsiveness and inclusion when discussing futures within education

What's the issue?

The way how the future is perceived and imagined is part of one's mental model and worldview. This poses a challenge: when education addresses the future, whose future is addressed? Who is left behind or in the margins? In democracies, the future is supposed to be negotiated by all to ensure a common ground where everyone's voice is heard and their rights are valued equally. Thus, future-oriented education can not be about a singular future but a plural future:

all the futures that we can negotiate for, and all the plural futures that we wish to simultaneously ensure for the plurality within our societies.

Empirical basis

Throughout our part-studies, hundreds of students shared their ideas, hopes, fears, uncertainties and imaginations about the future. Most of them campaign for a peaceful, equal and fair future, but the way this is imagined is different for everybody. They all have a unique perspective on the future, which reflects their attitudes about the society around them, other people, social class issues, gender, sexuality, disability, ethnic and cultural identity and so on.

For example, a student with reduced mobility wished for a future where they were "like everyone else". Another student envisioned not a future of fantastic technology, but a future without the pressure of gender expectations. A third student struggled to voice a view of the future, perhaps because the present seemed overwhelming enough. It is thus clear that futures thinking is also a personal matter, and that science education should not attempt to offer "one-size fits all" narratives about individual or collective futures.

Further reading

Developing Frameworks for New Theories in Futures Studies, Hejazi (2011)
Decolonizing Futures: finding voice and making room for non western ways of knowing, being and doing (Bisht, 2020)
Students' ownership of the future, cf. "colonization of the future": Facer (2012); Masini (1993, see p. 8); Hutchinson (1996)

Lack of metacognition in futures thinking

What's the issue?

Although during future-oriented activities, students can be guided to develop competences to think at the future in a better way, they often struggle to recognise and reflect on their futures thinking skills: they lack the words to express the gain obtained through the activity in terms of development of skills.

For example, 'future-scaffolding skills' are competences that can be developed by students to think at the future in a new way, by organizing pieces of knowledge and building systemic views, and by navigating across the complexity of knowledge, without trivializing the relations between local details and global views, the relations between past-present-future, and the role of individual and collective actions.

However, it has been observed a difficulty for students to verbalise the development of future-scaffolding skills, even in cases in which these skills are acted in specific activities. We mean by verbalization of future-scaffolding skills a specific metacognitive skill revealed when students talk about their experience in future-oriented activities expressing the changes in their ways of looking at the issues in terms of development of some abilities.

The difficulty for students to verbalize the development of future-scaffolding skills and, more in general, the lack of metacognitive skills about futures literacy is an issue that future-oriented science education needs to address for at least two reasons: i) make the students active protagonists of their own learning, by fostering metacognition skills; ii) make the students aware of the fact that learning science in formal and informal contexts is not only helpful to develop technical abilities but can pave the way for the development of skills that can be applied to a range of fields. All of this would make school science more relevant from a societal perspective for both teachers and students.

Empirical basis

This issue is one of the research results of *Part-study 6*, where, after a module on complex systems, students were found to have developed and to exhibit their future-scaffolding skills yet still lack the ability to verbalise these skills.

Further reading

Future-scaffolding skills: Levrini et al. (2019).
Operationalization and recognition of future-scaffolding skills: Levrini et al. (2021b).
Developing Futures Literacy in the classroom: Bol & de Wolf (2022).

5. Recommendations to futurize science education

In this Section, we present 14 recommendations to futurize science education and connect them with research-based issues presented in the previous section. The recommendations are grouped into three categories: *Why, for whom? General aims for science education* (see 5.1), *What? Contexts and contents of science education* (see 5.2), and *How? Pedagogical methods in science education* (see 5.3). The recommendations are given in the same order as in *Fig. 1*, and numbered with a corresponding Roman numeral. For a quick overview of the recommendations, see Section 2.

For each recommendation, we present its summary and some further insight into the theoretical and/or empirical background as well as potential barriers, results and our own related experiences within the FEDORA project.

5.1 Why, for whom? General aims for science education

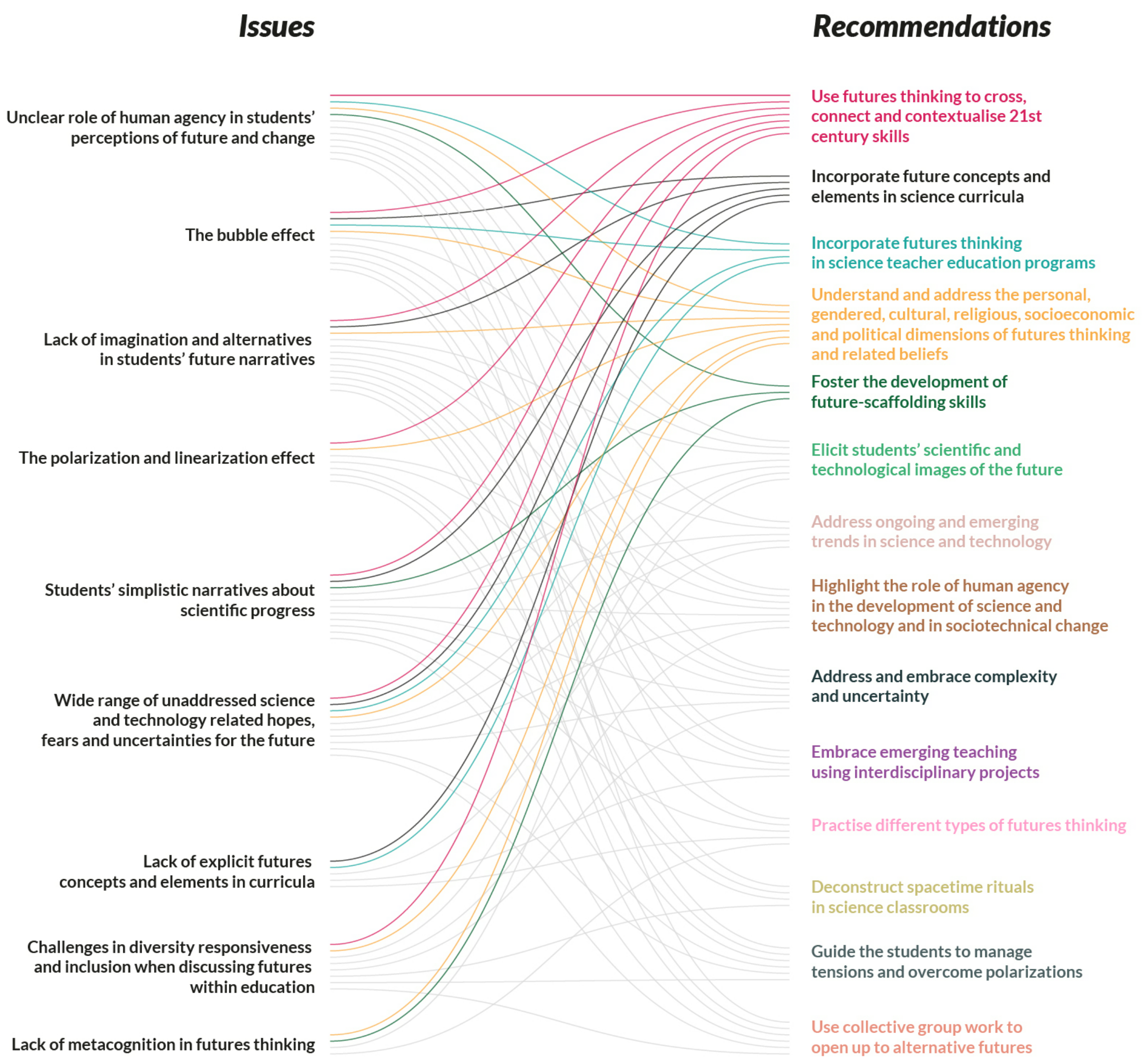

Fig. 3. The issues addressed by the Recommendations in this category (I-V).

The first category of recommendations (I-V) relates to the need to realign the general aims of science education. These recommendations are primarily intended for policy makers, curriculum developers and teacher educators.

Recommendation I: Use futures thinking to cross, connect and contextualise 21st century skills

Futures literacy is an essential competency for the 21st century (UNESCO). It can be seen as an additional skill, but also embraced as a way to cross, connect and contextualise other 21st century skills.

When envisioning futures, skills such as critical thinking, creative thinking and empathic thinking come together, especially when discussed in an interdisciplinary and collaborative way. It is a way to combine sense making and strange making skills (Bol & de Wolf, 2022).

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Lack of explicit futures concepts and elements in curricula
- Lack of metacognition in futures thinking

Background

To overcome the challenges of the twenty-first century in science and technology sector, students need to be equipped with the 21st century skills to ensure their competitiveness in the globalization era. They are expected to master the 21st century skills apart of just being excelled in their academic performance. Therefore, it is crucial to incorporate 21st century skills in science education (Turiman, et al., 2012).

But 21st century skills should not only be seen as the skills need to adjust to the environment (as bystanders), it should also support the attitude of young people to feel at home in in the world and to feel the agency to make it their own (as participator) (Biesta, 2013). Futures Literacy can be the bridge to connect both. In fact, the toolkit to navigate the present time seems to require the need to keep one's eyes on the horizon and deal with uncertainty on the individual and collective levels.

In *Part-study* 5, the need to address 21st century skills is addressed in curricula descriptions, but it remains a challenge for teachers, as all described separately, to find an overarching way to be able to integrate them into their already busy program. By elaborating on the future, it is possible to create a safe space in which many topics can be connected and skills can be contextualised.

Further insights

Barriers for the recommendation may include: When using futures literacy as an overarching umbrella teaching multiple skills, teachers need to understand and feel comfortable doing this - have knowledge on how to do this. When adding futures literacy to the spectrum, even as an overarching skill, teachers and curricula designers can see this as an additional skill and possible burden i.e. a competing skill in the already packed skills palette.

Expected results include: An easy and practical way to teach multiple 21st century skills at the same time.

Recommendation II: Incorporate future concepts and elements in science curricula

Young people go to school to prepare for the future, they are taught about the past, a bit about the present, but hardly about the future. As we live in a VUCA (volatile, uncertain, complex and ambiguous) world the importance of consciously discussing change and possible emerging futures becomes much more relevant (Stein, 2021).

Education often lags behind. Society continuously changes which puts pressure on schools because outsiders demand that schools' curriculum addresses the latest developments and possible directions. As a result, schools are always running behind. By the time they have incorporated the latest development in their curriculum, new relevant themes become apparent (Bol, 2018). Also in science education the answers are not always as straightforward as they seem, especially now in this VUCA world. Therefore the need to discuss futures becomes more absolute. One way to achieve this objective is to incorporate future concepts and elements in science curricula.

Issues addressed

- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Lack of explicit futures concepts and elements in curricula

Background

Futures thinking can be integrated in all types and levels of education (Bishop, 2012), also in science related classrooms. With the rise of Post Normal Science, scientific issues of which a straightforward research is incomplete, inadequate or inappropriate, the need to integrate futures concepts into science education increases (Gluckman 2014). This discourse highlights the societal, value-laden connections of scientific debates and activities, and calls for scientifically literate dialogue between various stakeholders. This perspective is naturally integrated through future-oriented science education, which inherently involves systemic, value-laden discourse around unknown futures. Furthermore, it bridges individual and collective levels of socioscientific issues.

In *Part-study 5*, when analysing the different secondary science curricula, we saw multiple indirect mentions of futures, such as change, imagination and uncertainty. This can provide a gateway to relate curricula content to futures thinking, as well as the desire to integrate actual and emerging issues into teaching that was indicated in several occasions in the different curricula. These curricular aims may gain additional clarity and coherence by explicit connection with the future.

Finland is one of the few countries in the world where futures concepts have recently (2014) been added to the curriculum description. This has resulted in substantial growth and interest in futures literacy by schools and teachers.

Further insights

Barriers for the recommendation may include: Rigid systems regarding curriculum change; the possible competition with other interesting and relevant issues and skills to improve curricula

Expected results include: Space and freedom to better prepare for a continuously changing future.

Recommendation III: Incorporate futures thinking in science teacher education programs

An effective teacher training program will help (new) teachers in staying updated on the latest methods and processes being followed in the classroom. The traditional manners of teaching, such as memorizing and theoretical learning, are giving way to more practical learning and new developments. To be able to, continuously, address these new developments, to address possible futures, teachers should become more futures literate.

Also in science teacher education programs, with its new transformative aims of science education for sustainable development, is it obvious.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Lack of explicit futures concepts and elements in curricula

Background

Teachers, including science teachers, have limited experience teaching about the future in their classroom. It was probably not something they were exposed to during their own education, at secondary level as well as in their teacher in training or science programs.

They have not been taught to think about the future in a systematic way themselves, and don't always have the confidence to experiment with it. Research has shown that teachers, as well as students, tend to stick to the 'probable futures' type of thinking and not question the prevailing assumptions underlying the 'probable future' (see e.g. Varpanen et al., 2022).

Yet, science teachers have the opportunity to turn the experimental inquiry-based science learning approach into an experimental attitude on the future. The tradition of experimentation can be built upon to integrate active elements in classes related to futures thinking in science. This can be achieved for example by integrating prototyping potential future technological objects and speculative designs in the classroom.

Further insights

Barriers for the recommendation may include: Teachers have busy programs and limited time to learn and experiment with new things. As the future doesn't exist outside our thinking about it, there are no direct right or wrong answers. For teachers and students alike, this requires being more comfortable with open-ended activity and a lack of objective evaluation.

Expected results include: Teachers feel comfortable to 'play' with the future in their classroom. It is easier for teachers to address emerging issues and for example the sustainable development goals. Students are better equipped to deal with uncertainty and ambiguity, to deal with change and to possibly influence it.

Recommendation IV: Understand and address the personal, gendered, cultural, religious, socioeconomic and political dimensions of futures thinking and related beliefs

Students live their lives surrounded by a rhetoric of imperatives and necessities. That rhetoric is upheld by various socio-political groups whose interest is to narrow the public debate down by certain orientations and assumptions, thereby predetermining or colonising the future (Hutchinson, 1996; Masini, 1993). To counter these incentives, transformative and emancipatory education needs to explicitly address that the future is not fixed, and that the purpose of a democratic government is to ensure all citizens are involved in envisioning and creating the future. Here, various perspectives ranging from personal preferences to demographic differences must be taken into account: students should be lead to understand that the future belongs to everyone equally.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change

- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education
- Lack of metacognition in futures thinking

Background

Perceptions about the future are an integral part of one's worldview (Lloyd & Wallace, 2004). Naturally, one's aspirations, fears and dreams can be immensely personal and important to the way one perceives oneself, others and the world. Furthermore, futures connect e.g. to political issues, and thus discussing futures brings classroom activity into a sociopolitical domain.

Pluralistic education aims to bring forward a variety of value-laden viewpoints and discuss them openly (Sund & Öhman, 2014). This is a necessary perspective in future-oriented education. Our framework advocates addressing students' futures view in holistic ways. While science and technology are key features, one's image of the future contains various hopes, fears, values and expectations. As students imagine their future, they are constructing their views of what is a good life, what is adulthood, what they want to achieve, their hopes of happiness, their fear of failure, ways of managing stress and complexity, and so on. Some key themes seem to be connection with other people and with nature, integration of family and working life, emotions, sense of agency and so on. Future-oriented pedagogy should be cognisant of these aspects, and also help students understand that future-related questions are often deeply woven into their values, not simply their forecasting ability.

Future-oriented science education should be thought of and communicated as an invitation into both expert and non-expert communities and the society as whole in all things related to science and the future world overall. In other words, it should relate to students' informed empowerment and agency, widening their imagination and self-efficacy by giving the students the scientific literacy to actively participate in future-making on small and large scales alike.

Further insights

Barriers for the recommendation may include: Challenges in sensitive issues; diversity responsiveness should not contribute to othering and exclusion

Expected results include: Seeing the world "as a process" should help students strengthen their own identity while also appreciating diversity; the future is equally uncertain and ambiguous to everyone, which should be construed as a context to experience and build equality

Experiences in FEDORA modules: FEDORA implementations take it as a starting point that students formulate their own visions of the future, and engage in equal discussion around these visions. In this manner, the implementations give students space to reflect on their own personal views, but also to relate to each other.

Recommendation V: Foster the development of future-scaffolding skills

There are competences that the students can develop through future-oriented science education and that impact their imagination and perception of the future. They are named future-scaffolding skills and they consist of abilities to organize pieces of knowledge and build systemic views (structural skills) and competences to navigate across the complexity of knowledge without trivializing the relations between local details and global views, between past, present, and future, and between individual and collective actions (dynamical skills). Teachers and educators need to foster in students the development of these competences, as well as the metacognitive ability of recognizing their achievement.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- Students' simplistic narratives about scientific progress
- Lack of metacognition in futures thinking

Background

Previous research in future-oriented science education (Levrini et al., 2019; Levrini et al., 2021) have shown that the development of future-scaffolding skills is of fundamental support to the change of students' perception of future that, from distant and unapproachable, becomes actionable. The agency on the present "with an eye at the future's horizon" (Branchetti et al., 2018) is supported by the future-scaffolding skills in two different ways. Structural skills, indeed, allow building a rational scaffolding for complex issues, for example by identifying the causal relationships, or the different disciplines or dimensions intertwined and in this way organizing disparate pieces of knowledge in comprehensive pictures. On the other side, dynamical skills are particularly suited to complexify the scaffolding and overcome linear thinking: to navigate back-and-forth the scaffolding that has been constructed, moving from details to global views, from the present to the future, from an individual to a collective dimension, from imagination to actions, from desire and aspiration to reality, from one discipline to another, and from a sense of necessity to a sense of multiple possibilities (Levrini et al., 2021). Moreover, it has been argued (Levrini et al., 2021) that these skills are not simply soft or transversal skills, independent or detached from any content and discipline: they can be nurtured and developed starting from a focus on the disciplinary issues of STEM disciplines, when suitably re-constructed (Duit, 2007). For example, exploiting what already exists in most school curricula, in physics it could be shown that science has developed a variety of modelling approaches to make predictions and build future scenarios, that span from the determinism of Newtonian mechanics to the epistemic uncertainty of quantum mechanics and the deterministic chaos of science of complex systems (Levrini et al., 2019). Also analysing specific artifacts like agent-based simulations in their physical, mathematical, and computational details can be a way to ground the development of future-scaffolding skills - both dynamical and structural - that, at the same time, provide a language to better dive into the disciplinary details of the artifact and help moving to the conceptualization of other societal issues (Barelli, 2022).

However, recent studies (Barelli, 2022) have shown that, even when the students are led to develop these skills and they put them into play in specific activities, some difficulties can persist for them to verbalise the development of future-scaffolding skills. Hence, a particular focus should be directed to make students aware of the importance of these skills and to recognize when they have obtained them.

Further insights

Barriers for the recommendation may include: Teachers could observe a misalignment between the skills displayed during the activities and the skills that the students can actually verbalise (see UNIBO issue #3). However, being the competence of self-perception “a cornerstone of both social and emotional development” (Kagen, Moore & Bredekamp, 1995, p. 18), when teachers observed this phenomena could take the opportunity to investigate together with the students the reasons behind this misalignment, in order to make the students active protagonists of their own learning, able to recognize the huge, transversal gain they can have from science future-oriented learning.

Expected results include: Through the conscious and aware development of future-scaffolding skills, the student would perceive the “scaffolding” of the future, its logical, spatial and temporal structure, but they will also be able to move back and forth across its levels.

Experiences in FEDORA modules: UNIBO studies: the phenomena of misalignment between skills in action and verbalised was pointed out in an intervention carried out with upper-secondary school students and in-service teachers (Barelli, 2022; Barelli & Levrini, 2022a; Barelli & Levrini, 2022b). Further studies will be directed to investigate the reasons behind this misalignment and ways to overcome it. In the UH module, future-scaffolding skills are practiced when discussing the complex system of the city of Helsinki.

5.2 What? Contexts and contents of science education

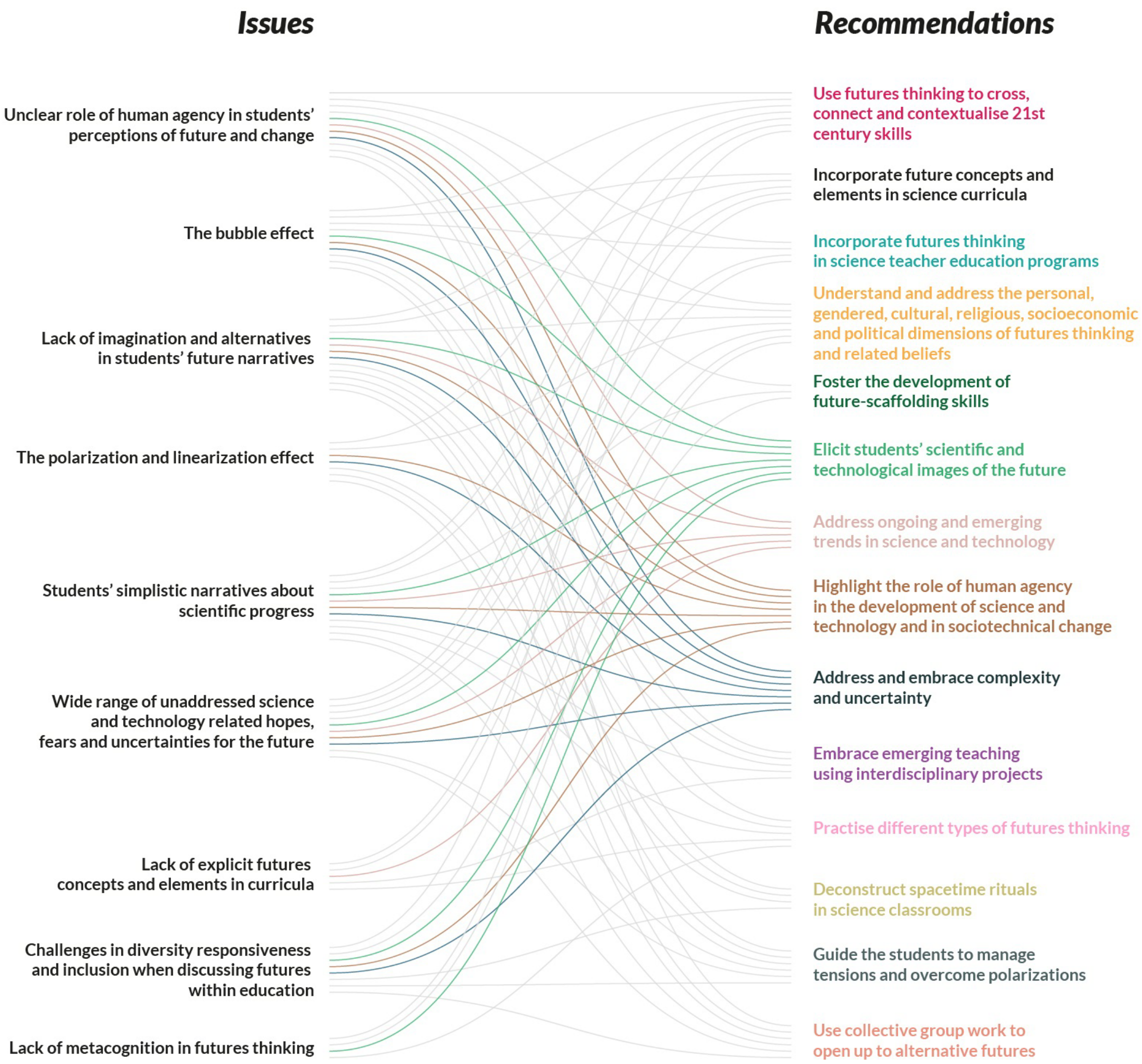

Fig. 4. The issues addressed by the Recommendations in this category (VI-IX).

The second category of recommendations (VI-IX) relate to the need to re-evaluate the contents of school science alongside the contexts in which science content is framed. These recommendations are primarily intended for local level curriculum developers, teachers, teaching material developers and teacher educators.

Recommendation VI: Elicit students' scientific and technological images of the future

While everyone thinks about the future in some way, many students have rarely or never taken time to thoroughly reflect on their images of the future. This kind of activity can be inspiring, thought-provoking, curiosity-inducing as well as frightening and confusing. Students have fears and concerns related to science and technology in the future, and it is helpful to explicitly address them in science classrooms. With future-oriented pedagogies, students come to terms with the unpredictability of the future and start to see it as openness to agency. Furthermore, as students become more accustomed to taking time to imagine various futures, they feel more prepared to face the complexity of the world around them, and connect the idea of their own future with the future of the world around them.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education

Background

All our part-studies indicate that students enjoy and find value in imagining futures, especially as a shared activity. It is also a task that taps into the transversal learning objectives in science curricula. As Facer (2012) has argued, framing the future as 'lived' and 'local' seems also to encourage students to think meaningfully and critically of sociotechnical change; in other words, it activates their socioscientific thinking skills. It seems plausible that such practices may help students also understand connections between themselves, social phenomena, and sustainability.

Imagining futures is in itself an exercise in futures literacy (see e.g. Miller, 2007; Poli, 2021), but given a scientific context, it can work as an avenue into contemporary science topics, socioscientific argumentation, science-technology-society-environment interactions and the personal, vocational and societal relevance (see Stuckey et al., 2013).

See for example Rasa, Palmgren & Laherto (2022) for a study on students' experiences on a future-oriented science course: students reported feeling hesitant about futures thinking, but then coming to terms with the uncertainty of the future. They realised that science and technology are not completed endeavours but ones that they are invited to via education. Furthermore, they found such pedagogies to combine science concepts with creativity in a refreshing manner. In fact, after the course, students seemed capable of articulating the development of their future-scaffolding skills (see the published paper for further details).

Notably, this creativity may be unfamiliar to educators too; in future-oriented education, it is typically emphasised that the goal is not to "know" the future but to tell stories that are useful (by giving ideas, inspiring, highlighting opportunities and challenges and so on). Thus future-oriented science education should not focus on simply assessing the plausibility of students' images of the future, but first work to elicit ideas that emphasise the dynamic, changing nature of the world (and humankind's scientific activities). Furthermore, educators should be aware that futures thinking links closely with individuals' values, and thus future-oriented activities should be demarcated as spaces partly outside clearly defined, scientifically accepted answers.

Further insights

Barriers for the recommendation may include: open-ended task requires flexibility in teaching; lack of materials; students may be unfamiliar with future-oriented activities and the value of e.g. scenario building

Expected results include: increased futures literacy; connections between one's individual and vocational and larger, societal-global futures

Experiences in FEDORA modules: The UH implementation ("My city of the future") supports the notion that students find much value in crafting futures scenarios. In the UH implementation, students also compare their visions to official, e.g. city planning related future policies. However, it seems that without additional feedback and guidance, after some time students' imaginative work no longer provides additional value. Thus, it may suffice to give students short, e.g.

single lesson workshops on exploring their views of the future, before moving on to more content-oriented, conceptual and guided tasks to enhance futures thinking.

Recommendation VII: Address ongoing and emerging trends in science and technology

Scientific and technological landscapes evolve rapidly, urging educational systems to keep pace. However, keeping pace is not enough; as education is always for the future, it needs also to be about the future. Thus, education should explicitly address questions of emerging technologies, open and promising questions in scientific research, as well as provoke interest in what lies beyond the current limits of knowledge. From climate change to artificial intelligence and from protein design to theories of everything, students should be led to understand that science is not complete, and many opportunities and challenges will require scientifically literate individuals to address them.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- Lack of imagination and alternatives in students' future narratives
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Lack of explicit futures concepts and elements in curricula

Background

Research has shown that students' images of the future involve extrapolations of the present but also, at least to a limited extent, discontinuities (e.g. major shifts in how societies are organised). From the perspective of "Vision III" scientific literacy (Sjöström & Eilks, 2018), it may be fruitful to explicitly address radical possibilities and risks, challenging business-as-usual scenarios and eliciting students' values (see e.g. Hodson, 2011).

Education should have a more proactive role in society, it should shape society. Schools should be very aware of what is going on in society (Bol, 2018). As a further argument, students should perceive science as an ongoing process of understanding the world. This requires having the capacity (as part of one's scientific literacy) to appreciate and expect potential increases in human knowledge in the future. As Hurd (1998, p. 409) argued, "a valid interpretation of scientific literacy must be consistent with the prevailing image of science and the revolutionary changes taking place in our society"; in other words, scientifically literate people should also be able to follow, to some extent, current events in the scientific world. This aim has been discussed also in terms of promoting relevance of science education (Stuckey et al., 2013). This kind of scientific literacy involves an awareness of key open questions in science. Furthermore, it highlights that scientific endeavours are open for agency, since they are not complete.

For example, in the I SEE project (https://iseeproject.eu/), pedagogies were developed to address issues such as quantum computing, carbon sequestration and artificial intelligence. Such initiatives indicate possibilities in updating aspects in the content of school science. In fact, some science curricula already address e.g. biotechnology in a future-oriented way. It may be fruitful to reexamine the scientific content and the extent to which scientific and technological futures are discussed in curricula.

Further insights

Barriers for the recommendation may include: Educators tend to feel insecure about discussing things that they don't know, or that no one has answers to; lack of materials; lack of access to cutting-edge knowledge, experts, and explanations; perceived disconnections with main curricular content; teachers need practice in alternative ways of futures thinking

Expected results include: Increases in curiosity, motivation, creativity; increased relevance of curricular content; career aspirations; autonomy, e.g. search for materials; increased understanding of the nature of science (NOS)

Experiences in FEDORA modules: The UH module "My city of the future" addresses the role of emerging technologies in the creation of a sustainable city of the future.

Recommendation VIII: Highlight the role of human agency in the development of science and technology and in sociotechnical change

It is quite typical for people to think of science and technology simply as the future. Thus, science and technology may be seen as vague but deterministic "powers of progress". However, some students see science and technology as more entangled with human agency: problems are solved and value-laden questions are addressed by collective effort to which students can see themselves contributing as experts or informed non-expert citizens. Such conceptions are more aligned with the goals of science education. Futurizing science education helps students connect science and technology-related hopes and fears about the future with agency. Furthermore, students can be led to connect agency with their own future: using the capacities gained in education to find their own niche in society.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education

Background

A wide range of studies supports the notion that images of the future may be dominated by technology-related hopes and fears (Angheloiu et al., 2020; Cook, 2016; Heikkilä et al., 2017; Lloyd & Wallace, 2004; Myllyniemi, 2017) alongside their optimistic or pessimistic expectations around sustainability (Cook, 2016; European Commission, 2014). In fact, Special Eurobarometer 419 (European Commission, 2014) indicates a general belief that "science and innovation", rather than "people's actions", will shape many of the key aspects of our future, ranging from security and health to climate change.

For science education, it seems a crucial task to cross the two categories implied in the Special Eurobarometer: science and innovation are also people's actions.

Science education should have a major role in promoting students' understanding of opportunities for responsible research and innovation (see e.g. Laherto et al., 2018) as well as democratic involvement in science and technology (see e.g. Bijker 2001; Hodson, 2003). Science education should provide critical scientific literacy to ensure a meaningful dialogue about the kinds of scientific and technological futures we wish to see emerge. Meanwhile, imagining various futures may show students that the world is not fixed, solutions and creativity are constantly needed, and that decisions and efforts will also influence their own futures.

However, findings from our *Part-study* 1 indicate that when discussing perceptions of the future with students, the role of agency should be addressed: who influences (creates, enables, campaigns for, opposes…) the changes that students imagine, as they imagine the future different from the present? Here, e.g. historical examples of societal-technical-scientific change could be used to emphasise the complexity of stakeholder interactions and the seeming paradox of making choices within systems that are hard to predict.

Furthermore, such discussions should not be thought of only as exercises in socioscientific argumentation, but should touch on students' own views about desirable futures, to counteract the "bubbles" and polarities that futures thinking may induce, and to allow diverse voices to be heard.

One key implication of our part-studies is the problematic nature of "technological fix" scenarios. While in these scenarios scientific and technological activity is valued as influential and positive, agency may be attributed to distant entities "out there", who come in and solve wicked problems with a single stroke (see also Cook, 2016). We recommend eliciting and problematising such narratives, instead emphasising the collective efforts of a multitude of actors in complex socio-scientific systems, and the realistic possibility of all students becoming involved in these collective endeavours. This would on one hand reflect the nature of socioscientific/sociotechnical change, and make science education more relevant for the student on the other.

Further insights

Barriers for the recommendation may include: Detachment of general skills and curricular content from "real world" issues; students' current limitations on agency / agentic beliefs: pessimism, lack of societal autonomy; lack of perfect resolution, lack of clear solutions

Expected results include: Increased personal, societal relevance; feelings of empowerment; value-based motivation; sense of transformative agency; deeper understanding of scientific activity as societally embedded

Experiences in FEDORA modules: UH implementation "My City of the Future" indicates students feeling empowered by taking legitimate part in future-making. Over the course, students met with experts from various fields, gaining insight into different ways of contributing to sustainability transition in cities.

Recommendation IX: Address and embrace complexity and uncertainty

Our society is marked by the presence of numerous complex challenges to which we do not know how to give a definite answer, or whether there is one at all. The educational process to which we have been accustomed has led us to always think in terms of the linear problem-solution paradigm, whereas complex challenges require a drastically different approach, one that accepts within it the idea that there are no definite solutions and that to address complex problems a multifaceted and a transdisciplinary approach is required. Therefore, incorporating the concepts of complexity and uncertainty within our worldview, without being overwhelmed by them, is one of the most necessary demands to make on the educational world. Science education, having the means and the terms to deal with complex challenges, plays an important role in this transformation process, enabling it to generate transversal change adaptable to many scenarios of everyday life for all.

Here, futures perspectives are useful. Through guided activities in futures thinking, students learn both "sense-making" and "strange-making", i.e. logical-structural and exploratory-imaginative skills to reflect on their relationship with the future. This organically introduces students to the complexity and uncertainty of the changing world and human life, and with guidance and support, students learn to see that complexity and uncertainty are what create opportunities to influence the world and find one's own path in it.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect

- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education
- Lack of metacognition in futures thinking

Background

Research literature shows that both students and teachers have issues when addressing topics related to future problems and complexity. The real problem lies in the fact that generally school problems in the world of science education are approached in a linear manner, where one-size-fits-all solutions are admitted and not much room for error is given. STEM courses that should focus on boundary topics find difficulties in their implementation due to barriers in the education system. Using Voros's (2003) conceptualisation of possible, plausible, and desirable futures, it is possible to introduce the scenario approach into science education, an approach that is widely used in uncertain future dynamics such as climate change (IPCC, 2022). These scenarios manage to cover different aspects ranging from the personal to the practical and institutional (O'Brien and Sygna, 2013). This addresses the so-called bubble effect and the "polarisation" effect, in that explaining and helping to understand the complexity of a certain issue on several levels, from the personal to the social, allows bridges to be built between worlds that are generally perceived as separate and not connectable.

Taking climate change as an example, i.e. a complex problem, it is important to make it understandable and not give the message that it is an easily solvable problem or make it even more complicated than it already is. Complex systems have the possibility to allow teachers and students to deal with the concept of uncertainty – science has always dealt with this topic. In this way it is possible to think of futures suitable for all in which uncertainty allows to act toward a preferred direction or scenario.

Shepherd (2016; Shepherd et al., 2018) divides the concept of uncertainty related to sustainability and climate change into 3 types: an uncertainty related to human feedback, an epistemological one, and an aleatory one. Knowing the differences between these three can allow to better understand the complexity of a given problem and to promote action towards it.

An activity on these three different types of uncertainty was carried out at the IDENTITIES summer school held in June in Barcelona (https://identitiesproject.eu), in which students were asked to work on the different types of uncertainty within their own disciplines. The activity allowed students to approach the topic of uncertainty and complexity from different perspectives, such as epistemological or methodological, and made it possible to understand how students from different disciplines viewed uncertainties within their field of expertise.

For example, in Rasa, Palmgren & Laherto (2022), we found that after a future-oriented science course, students reported seeing the future as more uncertain than before, but that this was a source of inspiration and hope; it required shifting to new ways of thinking. In the context of science and technology, future-oriented thinking nudged students to realize that not everything is known yet, and that they “will be needed” (see Rasa, Palmgren & Laherto, 2022, p. 18). This aspect of scientific thinking and expertise is conceptually linked to e.g. issues in Nature of Science (NOS).

Further insights

Barriers for the recommendation may include: Teachers may need practice and training to help students cope with uncertainty. Experiencing uncertainty and lack of resolution in the classroom may be unfamiliar to students and teachers. Students may refuse to accept a lack of answers.

Expected results include: Embracing uncertainty in everyday decisions; understand the complexity of future challenges; questioning of deterministic perceptions; questioning of static perceptions

Experiences in FEDORA modules: The uncertainty of the future was explicitly tied in with agency on a local scale in the FEDORA UH implementation: the students were led to familiarise themselves with the inherent uncertainty of future plans (for the city of Helsinki), and were then given the opportunity to be involved in the discussion about the future of the city.

5.3 How? Pedagogical methods in science education

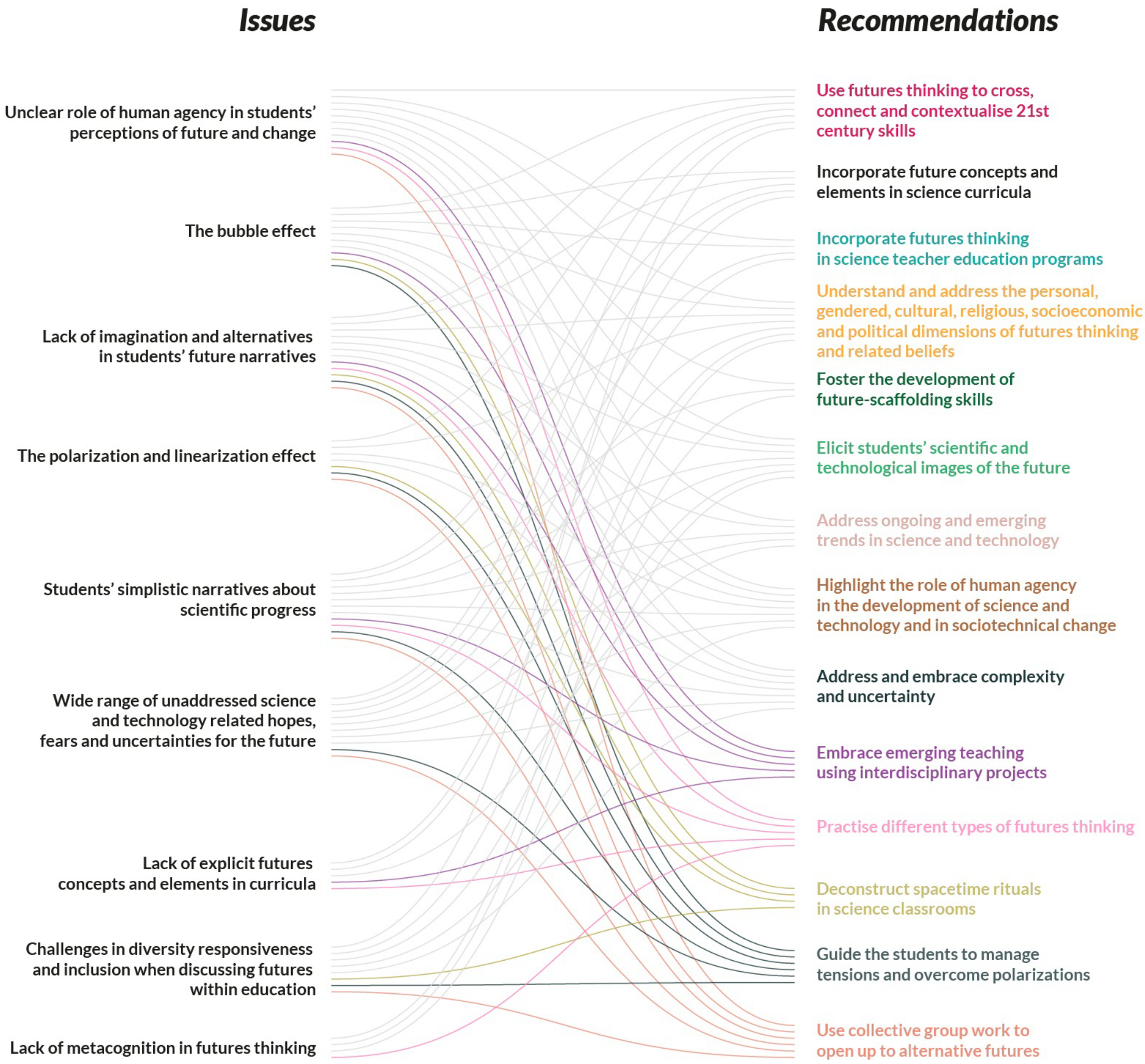

Figure 5. The issues addressed by the Recommendations in this category (X-XIV).

The last category of recommendations (Recommendations X-XIV) relates to teaching practice, school culture and classroom activities. These recommendations are intended to be seen as especially relevant for teachers, teaching material developers and teacher educators.

Recommendation X: Embrace emerging teaching using interdisciplinary projects

Emergent teaching is a style of holistic teaching in which you work with interdisciplinary projects that are also based on overarching and future oriented topics.

These projects create a space where science subjects overlap each other or even where science subjects get mixed with other subjects like social science, citizenship, and others. These projects support the connection of systems, it is easy to play with different time dimensions, and helps in creating more agency beliefs as the students are part of solution based discussions.

Especially when choosing a future oriented topic it will support the combination of sensemaking & strange making in thinking and experimenting with new combinations.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- Students' simplistic narratives about scientific progress
- Lack of explicit futures concepts and elements in curricula

Background

The concept of emergent teaching (Crowell, 2013) inspires teachers to teach with more spontaneity and creativity and helps transformative teaching in science education. It is an educational method based on, amongst others, jointly investigating overarching and future oriented topics. It is teaching in a holistic and interdisciplinary way, elaborating on real life topics (linking to the sustainable development goals and emerging issues mentioned in the different curricula descriptions), and their possible evolutions into the future (which links to opportunities of influence).

This style of teaching also supports the possibility to elaborate on the different future consciousness elements. Especially systems thinking, one of the skills mentioned a lot in curricula but difficult for young students to grasp, can be addressed when using multi- and interdisciplinary types of projects. The time perspective element almost always automatically arises as this evolves naturally when discussing an emerging issue this way. Meanwhile, agency beliefs grow when students are agents in their own learning (OECD Future of Education and Skills 2030).

Experimentation is mentioned a lot in the different science related curricula descriptions without indicating where and how to do this. Also interdisciplinarity is often cited, but when dividing topics and being very specific in what to learn there is not much room for combining ideas and subjects. Emergent teaching can bring an answer to these issues, especially if combined with futures concepts and activities.

Further insights

Barriers for the recommendation may include: The need to reorganize class time schedules and structures; adjust style of teaching (embracing uncertainty and ambiguity)

Expected results include: The possibility to address a topic according to a students personal interest; the ability to embrace the complexity and uncertainty around emerging issues. Increased sense of acceptance with not knowing.

Experiences in FEDORA modules: In the UH WP4 implementation "My City of the Future", students collectively imagine a desirable city of the future and shared these images with city officials. During their visioning, they engaged in guided transdisciplinary exploration of the development of a sustainable city.

Recommendation XI: Practise different types of futures thinking

Students tend to perceive the future mostly as an extrapolation of current trends. Yet, other ways to think about the future – developing alternative and preferable scenarios – have proven important for facilitating hope and agency. Given the central role of science and technology in young people's images of the future, it is important to practise alternative types of futures thinking in science classrooms.

Issues addressed

- Unclear role of human agency in students' perceptions of future and change
- Lack of imagination and alternatives in students' future narratives
- Students' simplistic narratives about scientific progress

- Lack of explicit futures concepts and elements in curricula
- Lack of metacognition in futures thinking

Background

A typical approach to analyze futures thinking in the field of futures studies is that scenarios, or images of the future, can be created from various orientations (see e.g. Bishop et al., 2007; Börjeson et al., 2006). The first type of orientation discusses what the future is likely to be (‘probable futures’), while the two other types of futures thinking concern what the future could be (‘possible futures’), and what it should be (‘preferable futures’) (e.g. Börjeson et al., 2006).

Empirical research has shown that both students and teachers tend to stick to the ‘probable futures’ type of thinking, perceive the future chiefly as a continuum of current trends and not question the prevailing assumptions underlying the ‘probable future’ (see e.g. Varpanen et al., 2022). The research carried out in FEDORA (*Part-studies 1* and *3*) has supported these findings.

Yet, futures research has also shown that positive images of the future have positive effects on an individual’s life (e.g. Rubin, 2013). Focusing on threats as well as not questioning ’automatic’ future-thinking patterns narrow down thinking and thereby limit the possibilities (Hutchinson, 1996), while the perspective of hope encourages to see alternatives and opportunities (Lombardo & Cornish, 2010). Through guided activity, students seem to be able to develop the skills to think more openly and systemically. It is possible that they can also develop the metacognitive tools and concepts to find limitations in their thinking, which may alleviate closed-down thinking.

Thus, in order to foster transformative agency and to keep different science and technology-related futures open, science education should teach versatile ways to think about the future, with explicit curricular notions towards this end. Techniques developed in futures studies and tested in FEDORA have proven useful for opening students’ eyes towards alternative possible scenarios. Most importantly, students need practice to be able to imagine futures based on values, dreams and choices; such thinking is needed to activate the projective dimension of agency (Emirbayer & Mische, 1998; Varpanen et al., 2022).

Further insights

Barriers for the recommendation may include: Curricular limitations – futures education is not part of the curriculum, need to incorporate it in science contents

Expected results include: Improved futures thinking skills; seeing more alternatives for futures; empowered to take value-based action

Experiences in FEDORA modules: During the UH "My city of the future" module, students have been inspired to understand there are different futures and different ways to create scenarios – especially the backcasting activity has been well received: students have said they wish these methods were taught in school.

Recommendation XII: Deconstruct spacetime rituals in science classrooms

Change is the only constant, but it can be perceived as scary. Openness, time-dimension and ambiguity are aspects that challenge a wide-spread image of science and the sense of safety it can provide. Implicit or explicit school spacetime rituals are activated to create "bubbles of comfort zone" that detach science learning from the complexity of society and the anxiety it can induce. To avoid polarization, we recommend developing spacetime rituals that keep together the need of safety and the curiosity to futurize science education. Indeed, re-appropriating the meaning of daily rituals as a possible way to move across time can help perceive a new sense of directionality.

A possible way to address the gap between what they study in schools and the societal challenge they are exposed to could be introducing interdisciplinary practices and extra-curricular activities that, starting from scientific knowledge as a solid baseline, can meet students' personal or social interests, guide them to the envisioning of diverse future STEM careers. This could help them feel closer and actors of their future, which is not separated and distant but starts from the work in the classroom, breaking their rituals' bubbles.

Issues addressed

- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect

- Challenges in diversity responsiveness and inclusion when discussing futures within education

Background

School still appears as a source of normative and soothing rituals that, even in a pandemic era, can offer certainties and a sense of normality.

This is particularly true for the classes of mathematics and physics. They are seen either as sources of a-historical, unchangeable knowledge whose teaching cannot be affected by contemporary societal crises. For example, science and mathematics knowledge are intended to be crucial for students education and their culture. However, without spending time and effort in highlighting how that knowledge can shape a culture able to deal with the current SSI, students tend to separate on one side what they are asked to study in school, from what society asks and needs to be done.

School and, in particular, science school has a very weak, if any, role to form any sense of social agency. Despite all the recommendations and the claims, the empirical study we have carried out during the pandemic implies that science education is currently mainly focused to prepare students as STEM professionals rather than as social actors or responsible citizens. This direction should be redirected to avoid creating another detachment between who the young will become in the future (professionists) and how they could reach that possible future through many smaller steps (agency).

Further insights

Barriers for the recommendation may include institutional barriers and habits (e.g. the timetable and the classroom spaces); epistemological barriers – kwowledge as transmitted stuff vs knowledge as fabricated stuff; emotional barriers – emotional tension between need for safety and curiosity for society and its evolution.

Expected results include: epistemologically, kwowledge as transmitted stuff vs knowledge as fabricated stuff; emotionally, recognising that physics learning is a locus for identity development

Recommendation XIII: Guide the students to manage tensions and overcome polarizations

The "polarisation" effect related to the future is an articulated phenomenon that can emerge in relation to various dichotomies: personal-societal, functional-aesthetics oriented, good-bad, natural-artificial, and certain-uncertain.

Teachers and educators are recommended to identify them when they emerge in class and guide the students to elaborate ways to manage irreducible tensions without collapsing to the simplest solution represented by the choice of one of the poles.

Issues addressed

- The bubble effect
- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education

Background

In *Part-study 6*, reported in Barelli et al., 2022, ways of grappling with the future have been observed in secondary school students' essays and methodological tools have been elaborated to identify and characterize them. The analysis led to the definition of "polarisation" and "complexification" attitudes that represent the ways in which the students' narratives are positioned with respect to a bunch of dichotomies that represent alternative ways of looking at a particular issue. The dichotomies have been formulated as couples of poles, i.e., opposite, very generic adjectives that do not contain any reference to the specific themes, that are: personal-societal, functional-aesthetics oriented, good-bad, natural-artificial, and certain-uncertain. Each dichotomy is projected onto each macro-area to obtain specific dichotomies. For example, the personal–societal dichotomy, when projected onto the science and technology theme, becomes a dichotomy that contrasted a personal use of science and technology and a societal one; when projected onto the theme of relationship, the personal–societal becomes a counterposition between a restricted circle of people around oneself versus societally oriented relationships, open to conceiving the diversity of people around.

This structure made of a series of dichotomies becomes a tool for looking at students' future essays, that can be useful at least for two stakeholders: it can help researcher and teachers to recognize if a student has articulated his story aware of the complexity that the future as system has, even if only in relation to one theme (e.g. technology and science). Moreover, this tool is also intended to be useful for students to become aware of where their narrative can be positioned considering dichotomies as the space extremes, on which they do not necessarily have to position themselves totally and exclusively, but considering intermediate conditions. Also, having researchers, teachers and students better placed in the myriad possible positions within these dichotomies can help to better see where the various actors can act in the future.

Due to the limits of current data collection tools as well as the need to help students identify and problematize polarizations, the design of a SenseMaker® questionnaire has been elaborated. The questionnaire contributed to feeding a collaboration with #OurFutures project, recently launched by the European Commission to collect future narratives all around Europe.

Further insights

Barriers for the recommendation may include: emotional barriers, since polarisation is a simple way to manage fear and issues; epistemological barriers: complexity is a demanding approach that requires deep immersions in the science of complex systems and the recognition of its interdisciplinary character.

Expected results include: epistemologically, moving from a binary/polarised classical way to analyse phenomena to complex ways; emotionally: accepting complexity.

Experiences in FEDORA modules: UNIBO experiences show that the expected results can be achieved.

Recommendation XIV: Use collective group work to open up to alternative futures

Documented experiences from future-oriented activities have shown that when discussing the future together students are able to discuss and connect multiple ideas, learn from each other, stimulate imagination, and see different alternatives. Group work on futures imagination creates a collective energy, inspires hope, sparks empowerment and ideally makes one feel more strongly connected with and part of the future.

Issues addressed

- Lack of imagination and alternatives in students' future narratives
- The polarization and linearization effect
- Students' simplistic narratives about scientific progress
- Wide range of unaddressed science and technology related hopes, fears and uncertainties for the future
- Challenges in diversity responsiveness and inclusion when discussing futures within education

Background

Collective aspects of essays (*in Part-study 4*) opened up discussion amongst young people of sharing multiple perspectives on the future. As opposed to an individual writing task, this way of creating a future vision already opened up thinking in alternatives and being aware that there are various types of preferable futures out there, not only the one most familar to you. However, it can be worthwhile to switch between individual activities related to futures thinking and collective ones, depending on what learning objective is sought.

The discussed future visions also become richer and less simplistic, as new ideas and connections are made, also regarding scientific advances and innovation. Furthermore, collective activity is a natural way to diversify the conversation about the future, with the caveat of some limitations within a homogenous group. This strong connection with collective "futuring" is reflected in research literature on e.g. the concept of futures literacy (see Mangnus et al., 2021).

Collective group work can also address students' science and technology related fears and uncertainties for the future (Rasa & Laherto, 2022), reduce polarised attitudes and enforce students' sense of agency.

Further insights

Barriers for the recommendation may include: Facilitating group work asks for different types of preparation and teaching; when facilitating group work it is important to create inclusive conversation, which is not always easy.

Expected results include: Students are conscious of other narratives and ideas about the future; it opens up to possible discussions on diversity, inclusiveness and alternatives.

Experiences in FEDORA modules: In all FEDORA implementations, collective work was found to be a useful way of engaging in deeper and more systemic exploration of alternative futures.

6. Discussion and summary

The work presented here, the Framework to Futurize Science Education, elaborates the concerns in young people's perception of the future as well as misalignments between these concerns and curricula, and suggests how science education can provide students with tools for connecting with, and finding agency within, their personal and global futures. The framework, consisting of 9 issues and 14 recommendations to futurize science education, is based on extensive research carried out in six different part-studies in Finland, Italy and the Netherlands.

The recommendations are already employed in the FEDORA project to develop future-oriented modules for upper secondary schools in Finland, Italy and the United Kingdom. The FEDORA partnership is committed to extend the diffusion of these ideas to futurize science education after and beyond the project. In addition to the development of pedagogies and modules, futurizing science education requires action and cooperation from various actors: the 14 present recommendations to futurize science education are targeted for science teachers, policy and curriculum makers, teaching material developers, teacher educators and others in and adjacent to the educational field.

As the work continues, the recommendations will be combined with recommendations emerging from two other FEDORA work packages, WP1 ("Aligning science teaching/learning in formal contexts with the modus operandi of R&I") and WP2 ("Exploring new languages, narratives and arts in science education") to come up with "a model for science education for the society of acceleration and uncertainty" (WP4) and "Recommendations for proactive and anticipatory policymaking" (WP5).

Furthermore, the framework presented here aims not only to serve science education policies and practice, but also academic research on science education. Both the issues and the recommendations offer several openings for research agendas and projects. For example, there are open questions relating the concepts of agency, uncertainty and future-oriented competences to science education. The opportunities and challenges of types of futures thinking, along with various time scales from students' early-career futures to transgenerational futures, have seen little if any research as of this time. The roles of students' emotions and identities in shaping their futures thinking and its integration with scientific literacy, as well as differences between cohorts and most effective pedagogical and supporting methods also should be fruitful avenues for further research.

7. References and further reading

7.1 FEDORA and related outputs

The website of the FEDORA project:
https://fedora-project.eu

Future-oriented Science Education Manifesto:
https://www.fedora-project.eu/wp-content/uploads/2022/09/Manifesto_October_2022_18.pdf

7.2 Original research that contributed to this Framework

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Recommendations

1. Use futures thinking to cross, connect and contextualise 21st century skills

2. Incorporate future concepts and elements in science curricula

3. Incorporate futures thinking in science teacher education programs

4. Understand and address the personal, gendered, cultural, religious, socioeconomic and political dimensions of futures thinking and related beliefs

5. Foster the development of future-scaffolding skills

6. Elicit students' scientific and technological images of the future

7. Address ongoing and emerging trends in science and technology

8. Highlight the role of human agency in the development of science and technology and in sociotechnical change

9. Address and embrace complexity and uncertainty

10. Embrace emerging teaching using interdisciplinary projects

11. Practise different types of futures thinking

12. Deconstruct spacetime rituals in science classrooms

13. Guide the students to manage tensions and overcome polarisations

14. Use collective group work to open up to alternative futures

Get inspired, learn more, and expand your views!

The Framework to Futurise Science Education, which expands on the recommendations listed here, will be available on www.fedora-project.eu/ in November 2022

Read the Future-oriented Science Education Manifesto: www.fedora-project.eu/wp-content/uploads/2022/09/Manifesto_October_2022_18.pdf

Navigate www.fedora-project.eu/deliverables

FEDORA - Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty - This project received funding from the European Union's Horizon 2020 Research and Innovation program under Grant Agreement n° 872841
www.fedora-project.eu

FEDORA LEARNING BRIEF
on futurising science education

FEDORA

Global sustainability crises and accelerating societal and technological developments demand science education to address not only the past and present but also the future.

We lay the groundwork for future-oriented science education that provides students with tools for deeply connecting with, and finding agency within their personal and global futures.

We have conducted five studies on young people's futures perceptions and one study on European curricula. The studies on perceptions focused on how students relate to "agency" (e.g. who influences scientific or technological change and how), polarisations and rituals creating "bubbles" of safety, imagination, hopes and fears and their own futures' thinking. In the curricular study, we focused on identifying explicit and implicit links to future-thinking skills in European science curricula for secondary schools.

Through these investigations, we identified nine key issues to be addressed by future-oriented science education.

Furthermore, based on the findings of the studies, we propose a set of 14 recommendations to futurise science education. The recommendations aim to 1) address problematic issues and limitations in students' futures' thinking, 2) connect futures concepts with scientific and technological skills and knowledge, and 3) address related aspects of educational design and school culture.

Towards future-oriented science education