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O5 – Recommendations for policymakers

Key recommendations from the I SEE project for making science teaching and learning relevant to students' futures and STEM careers

I SEE

It's your time to imagine the futures

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Overview

What can the I SEE project tell us about bridging the gap between schools and society? I SEE involved designing, creating and testing four teaching-learning modules on complex topics that are highly relevant and important to the future: climate change, carbon sequestration, artificial intelligence and quantum computing. At the core of the module design was the goal to push students to aspire and imagine their futures in the context of these future-oriented scientific issues and possible STEM careers. The main design elements that aimed to achieve this goal were:

- Future-scaffolding skills
- Futures orientation
- Authenticity
- Inclusion
- Outreach

The following recommendations highlight ways to break down the barriers between schools and society in order to better prepare students for an uncertain future and enable them to see their place in it.

Chapter 1 – How can science teaching help students build a scaffold towards the future?

Simply put, future-scaffolding skills are the skills to build a scaffold into the future. The term was coined by the leader of the I SEE project, Professor Olivia Levrini, to highlight the potential for science teaching to be relevant for students' personal, social, professional and scientific futures by developing the capacity in students to aspire, envisage themselves as agents of change, and push their imagination towards future careers in STEM. One aim of the I SEE modules is to foster these specific skills in students, including: action competence (the ability to take enlightened action), scenarios thinking, dynamic thinking (moving back and forth between present and future, local and global, individual and society), thinking creatively to imagine new possibilities for action, recognizing logical relationships (problems, objectives, solutions, pros/cons), strategic thinking and planning, risk taking, thinking beyond the realm of possibilities, managing uncertainty, and creative thinking.

These skills were identified as ones that address the perception of the future as threatening and uncertain that leaves many students in a state of „frenetic standstill," unable to take action individually and as members of society. The modules foster future-scaffolding skills by giving students the opportunity to work practically and emotionally with ways to understand and approach uncertainty, and to manage and plan for possible future scenarios, especially their self-defined desirable ones. These skills are by their nature transdisciplinary and serve to help students relate to the future-oriented scientific issues irrespective of their academic backgrounds. They also help to make these issues and topics appealing to students who may feel a STEM career is not for them.

Students who participated in the I SEE module implementations describe in questionnaires and interviews that the lessons have two effects on their perceptions of the future: widening and approaching. Their perceptions of the future widened in the sense that they gained new ways of thinking about and approaching problems, saw new possible actions they could take (in their personal and professional lives and in their roles as citizens), and widened their views towards science and scientists. Their perceptions of the future approached them in the sense that the future felt closer, became more concrete, and became something they could start acting on in the present.

The identification of future-scaffolding skills, how they feed into changed perceptions of the future, and what teaching and learning methods foster them is the hallmark of the I SEE project and our recommendations for bridging the gap between school and society by making science teaching more relevant.

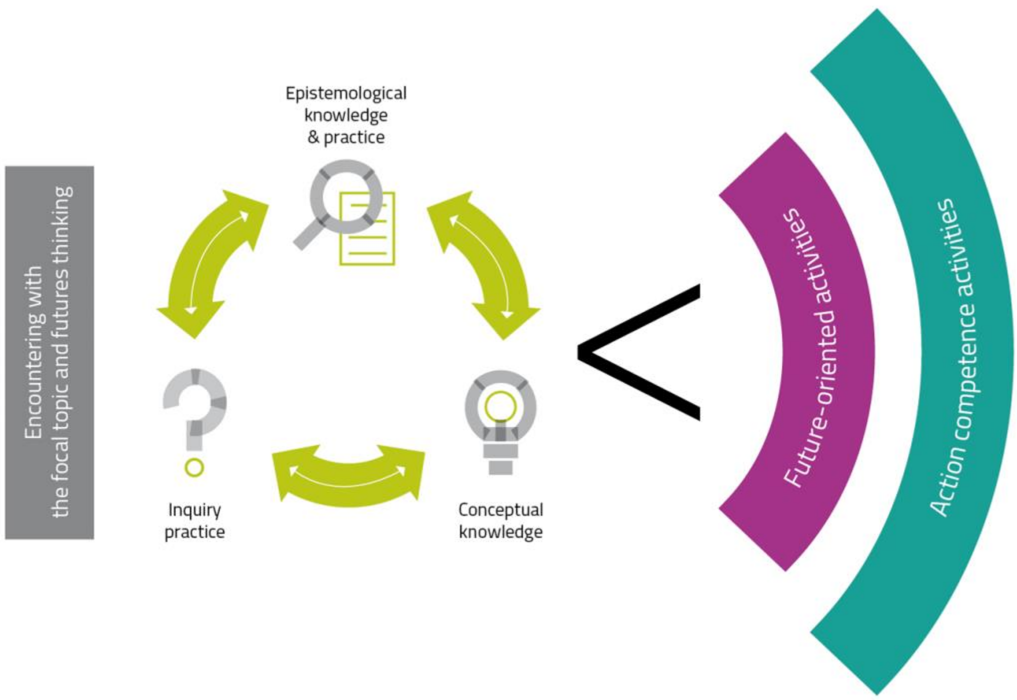
Chapter 2 – What kinds of teaching and learning methods support development of FSS in students?

The I SEE project seeks to innovate science teaching with methods that are not traditionally found in science classes, with the aim to bring the future into teaching and teaching into the future. It does so through the choice of topics and issues addressed in the modules, and the methods used for teaching and learning. The topics chosen for the modules developed in the project were selected because of their relevance to the future, their complexity, and their relation to students' experience of the future as a source of uncertainty and even anxiety. It may be that these topics tend to be avoided by science teachers because of a lack of expertise, or simply because teachers feel ill-equipped to approach them due to their complexity and inherent uncertainty. The methods used in the I SEE modules make it possible for any science teacher to use the modules by offering an exploratory approach in which teachers take on a different role from the conventional science teacher role as an authority on the subject.

Curricular and time constraints are also important factors determining teachers' ability to work with these future-oriented scientific issues, therefore it is critical that curricula change to reflect these highly relevant topics and that resources and support are made available to enable teachers to take them on.

The graphic below shows the pedagogical model developed by the I SEE project to represent the key elements and methods that support the development of future-scaffolding skills in learners.

Figure 1: The I SEE model



The model is designed to be followed from left to right, and shows how the parts of an I SEE module fit together to guide the learning process towards development of future-scaffolding skills. Examples of all of the kinds of activities described below can be found under the "Teaching" tab of the project website.

The process begins by engaging students with the topic and relating the topic to futures thinking. These „encountering" activities spark students' interest and give them a holistic idea of the topic. Futures thinking is introduced in relation to the topic right from the start, so the view to the future is established and remains throughout the rest of the learning process.

The next part of the process involves deep transdisciplinary learning on the fundamental concepts involved in the topic as well as the epistemological practices that lie behind knowledge creation in the topic. Learners are involved in inquiry practice activities that emulate research and innovation in the field so that they gain insight and experience into scientific practice in the wider context.

The conceptual, epistemological and inquiry activities benefit from input from outside experts. Inviting experts in the field into the learning setting or taking learners into the field means both that teachers do not have to be the experts themselves in all aspects of the topic and that bridges are built between school and society. The latter reinforces the authenticity of the module and plays an important role in exposing students to new possibilities for STEM careers. Exposure to the field and the people who work in the field gives students an image of STEM work and makes more real the fields of science and technology that can seem distant, unfamiliar, and even exclusive to many young adults. In the I SEE project we found that it is important during these moments of exposure that the outside experts relate to the students how their interest led them down their career path, starting from when they were the same age as the students.

The „<"- shaped part of the module represents the bridge between conceptual, epistemological and inquiry activities to future-oriented activities. Bridging activities relate the new scientific understanding and competences the students have gained so far in the module to their relevance for the futures. The conceptual, epistemological and inquiry activities serve as the foundation for students to be able to then approach the module topic from a futures perspective, and further work with it in an action competence approach later in the module. The bridging activities help students make this transition from more traditional science teaching to innovative future-oriented activities that challenge their critical and creative thinking.

Future-oriented activities are key to developing future-scaffolding skills through the module. They involve presenting and working with new ways of thinking about the future, especially in terms of scenarios. In this perspective, the future becomes not one but many possible scenarios, and the ones that will be realized is determined by many factors. Future-oriented activities engage students into this perspective in relation to the module topic.

Finally, action competence activities take students' new scientific knowledge and skills on the module topic, look at it through their new perspectives on the future, and synthesize them into action plans for a desirable future. These activities demand the most independence of the students and can serve as a comprehensive evaluation of the module as students show mastery of newly gained concepts, skills, and perspectives by applying and using them to undertake the action competence tasks which include systems analysis, strategic thinking and planning, futures forecasting, role playing and performance.

This part of the module has particular impact on students‘ ability to imagine a desirable future scenario for a problematic topic and to see themselves having a role to play in bringing about the desirable future. Students expressed in interviews that imagining a desirable future and articulating their plans to make it come true made the future seem brighter and closer, and their imagined roles for themselves as STEM professionals seem more realistic and attainable.

Careers in STEM are demanding with accelerating changes in the field and increasing need for responsible research and innovation. Working to foster future-scaffolding skills—like thinking beyond the realm of possibilities, risk taking and managing uncertainy—in students helps prepare them for the rapid change and even unpredictability of STEM fields. Scenarios thinking, dynamic thinking, recognizing logical relationships, strategic thinking and planning, creative thinking, and action competence are all future-scaffolding skills that support students to stretch their minds to discover new ways to address socio-scientific issues. These kinds of future-scaffolding skills, which are both practical and aspirational, will prove increasingly important as adaptation, innovation, and ethical leadership become more and more needed by the labour market and not least in STEM fields. The ability to see a desirable future for oneself and society and to be able to build a bridge into that future will be, indeed already are, the most in-demand skills educational institutions can give their learners.

Educators do not need to use the I SEE modules in their entirety to build up future-scaffolding skills in students. Some activities in the modules lend themselves well to being used on their own, and in the I SEE project many were tried out by teachers in this way with good outcomes. More importantly, the underlying principles, approaches and methods described above can inspire and inform any educational endeavor, formal or non-formal, that strives to make learning relevant personally, professionally and societally and develop capacity in learners to aspire and work towards a more desirable future for themselves and the world.

Chapter 3 – Seeing the futures: Orienting science teaching and learning in times of uncertainty

Even though the future is by definition unknown, it is not totally unknowable. Futures studies is an interdisciplinary field that addresses the uncertainty of the future by working with information to anticipate and foresee possible future scenarios. In education, futures studies approaches can inform pedagogy to dispel the mystery and the anxiety-inducing uncertainty of the future in order to make possible future scenarios something that can be worked with in teaching and learning.

The I SEE project responds to the question, „How can we futurize science education?" Firstly, we recognize the importance of acknowledging and addressing the tension learners feel for the future and the global crises that threaten a good future for all. Secondly, we address the sometimes perceived irrelevance of science education practice for preparing students for future STEM careers, which can explain partly student lack of interest in and bias against science subjects. Thirdly, the project developed activities that aim to empower students to have influence on their own futures and the future of society, based on the view that the future is one of many possible scenarios that can be affected by actions in the present. In particular, these activities encourage students to see STEM fields as possibilities for their futures.

Acknowledging students' fraught relationship not only with the future, but also with science and technology, is an important first step in working with future-oriented scientific issues and the future. Young learners have a need to feel understood and supported by their teachers and the educational system; this can mean educators taking on new roles to help them cope with the sense of threat they feel global crises pose combined with the sense of the lack of education adquately preparing them for the future. The main goal in acknowledging students' anxieties about their futures and the future of the world is to open up new ways of thinking about the future, presenting it rather as an open horizon that can be creatively explored and that specific future visions can be supported by conscious action in the present.

To address the perceived irrelevance of science education in preparing students for their studies and careers, educators can use lessons to show how science and technology can inform construction of future scenarios. In these activities, students use their scientific knowledge and skills to not only forecast possible futures, but also to back-cast to the present from their desirable future scenario. In applying science to desirable future scenario building, students experience the importance and relevance of STEM. Science learning becomes a tool for understanding complexity and uncertainty; skills in STEM become valuable for building a good future for students personally, professionally and societally.

Science itself and the scientific method imply a strong link to the future. The endeavor to know, discover, hypothesize and experiment are intrinsically directed toward the future. Science teaching and learning can highlight the nature and purpose of science more clearly and use it to show the potential of science to shed light on the future and provide tools to help formulate and approach the problem of the future. This approach can change students' negative attitudes towards science while at the same time make science education more relevant to the reality they are facing. Science education can then support young people in projecting themselves into the future as agents and active persons, citizens and professionals, and open their minds to possibilities, both for the world and for themselves.

In shifting attitudes towards STEM and the future, the potential opens up for empowering learners to relate possible future scenarios to their present actions. The I SEE project developed several activities that let students imagine desirable future scenarios on personal, professional and societal levels. These activities are creative, playful and open but also rigorous and guided in how they ask students to apply scientific concepts and methodologies gained from the modules. The main learning outcome, for students to be able to connect actions in the present to certain future scenarios, is reinforced by tasking them with articulating strategies for a desirable future and tracing that future vision back to the present. In interviews, students expressed that this approach was the most inspirational, many even giving examples of actions they had decided to take just after participating in I SEE, such as signing up for courses related to these issues to learn more, organizing actions like car sharing and tree planting in their schools and communities and becoming more active politically.

One of the main goals of the project is to create an approach in science education that addresses head-on the problems posed by global unsustainability, the uncertainty of the future, social liquidity and the irrelevance of science education for young people and their future. While employing a futures studies approach in pedagogical design for science teaching and learning is challenging, it has great potential to reorient science education towards the future and enable students to see the relevance of STEM to their lives as part of the solutions to the world's problems.

Chapter 4 – Making science topics authentic

Creating a sense of disciplinary authenticity – that students experience science lessons as reflective of real world science practice – is key to making science education relevant and thereby making students feel they are learning „real" science that prepares them for future STEM studies and work. In the I SEE module design, two parts are responsible for providing authenticity. The conceptual, epistemological and inquiry cycle is the part that involves innovation within traditional science teaching to bring it closer to real world STEM topics and practices. The second part is the orientation to the future, both embedded in the pedagogical approach and in specific activities. In the future orientation approach and activities, STEM topics and practices are directly related to issues that are highly relevant to the students' futures, personally, professionally and societally, making the lessons feel more authentic.

Lack of interest in STEM is related to students experiencing science teaching and learning as irrelevant to them as well as inadequate to prepare them for future STEM studies and work. In the conceptual, epistemological and inquiry activities, the I SEE project emphasizes learning about the most up-to-date concepts within the module topics (which themselves are chosen for their importance for students' futures) using methodologies that are used in the field. Students get to try out STEM practices for themselves, often with professionals from the field taking part or contributing. Epistemological activities in particular give students metascientific understanding as to how knowledge is created and why practices are the way they are in the field.

The second part of the module design that contributes to authenticity is future orientation as an approach and the subject of some activities. The future orientation of the modules starts already with the choice of topic. Getting to learn about topics like artificial intelligence, quantum computing, climate change and carbon sequestration raises interest right away as these topics are still atypical for science classes. Part of the encountering the topic activities includes explaining the selection of the topic and its importance for the future, which gives students the sense that they are learning about something new and important. Then, the openness of the future orientation approach in how it takes an exploratory view to the possible future scenarios underlines this sense of novelty and discovery. It brings the students on board as co-investigators of a challenging topic that has not been fully understood or addressed yet in the field. This is further reinforced by exposing students to role model professionals in the field who relate their personal career stories and tell the students about the kinds of roles and careers that are needed in the coming years.

These strategies apply not only to formal science education, but also to science centers, educational centers and any scientific educational enterprise, like public or private institutions with an educational department or mission. In some cases it can even be easier for non-formal education to work in these ways with learners because of their greater flexibility. Universities, research institutions and private firms can also benefit from following these recommendations as they can have direct impact on their potential future workforce. Using real-world, complex topics and incorporating research and researchers into formal and non-formal education can be a challenge, but the reward in delivering authentic learning and engaging students in possible future STEM careers can be transformative for their perceptions of the future.

Chapter 5 – Including all students in science learning

Science education needs to acknowledge diversity and look at diversity as an invaluable resource for deepening student engagement and increasing personal and societal relevance of STEM. The inclusive education approach means teaching in ways that enable all students to engage and learn. Part of student disinterest in science education can be traced to traditional science education practices that alienate or exclude some learners. The I SEE project involves deep innovations to build inclusive pedagogies into the module design including affective approaches, multiple modes of participation, self-defined role articulation, transdisciplinarity, relevance, and development of future-scaffolding skills. Premising science education on an inclusive view of society is critical for making STEM research and innovation socially responsible and a force for greater equality in the future.

The I SEE approach is intrinsically affective and aspirational. In asking learners to imagine dream futures for themselves and society and to define the roles they and others must play to achieve those dreams, students realize that many different kinds of people must work together to bring about a desirable future for all. In the action competence activities, learners elaborate their definitions of these roles, define the step-by-step actions each person must take to realize the desirable future, and finally actually take on the roles they have imagined when they perform their future scenarios for the class. This kind of emotional and openly imaginative activity is not usually at home in science lessons, and elicits strong responses particularly from students who feel anxiety about the future and their perception of the role science plays in creating the future.

The action competence approach involves building the capacity in students to make collective, enlightened decisions and take action on issues. Learners lead the process by deciding together what issue is relevant, defining what kinds of information they need to be able to make an informed decision on the issue, gathering the information, making a strategic plan for action, and, last but not least, starting their action plans. In I SEE, the action competence approach forms the basis for the final activities in the module in which students choose themselves an issue related to the module topic that they want to work to address.

Because the action competence activities give students choice in the issues they work with, they are free to relate to the topic from many disciplinary angles. They are grouped by issues of interest, which does not necessarily mean similar disciplinary interest. Then, in their issue groups, the students lead their research into the issue and decide what is needed to address it. They define the roles they will take on in their strategic plans and create their final performances together. In this way, the action competence activities have built-in multiple modes of participation, allowing for all students to find a way to engage and lead their learning. Because they work with other students in the process, they gain an appreciation for the different contributions and talents their fellow learners have to give.

During the I SEE summer school, students from Finland, Italy and Iceland came together to pilot the module on climate change. The cultural diversity experienced during the summer school was cited by students as one of the main sources of informal learning, and was described as very impactful. Students spoke of realizing how the different contexts we live in influence what issues are important to us, and expressed one lesson learned as being able to put themselves in others‘ shoes. This was made possible in activities that dealt specifically with values and framing arguments for or against different possible future scenarios.

During the other module implementations in all three countries, students from different cultural, socio-economic, and academic backgrounds took part. In Finland a case study was conducted on the implementation of the climate change module with students with disabilities. The thesis can be found under the "Resources" tab on the project website.

Diversity as a valuable resource was made apparent during activities in which students interviewed people they knew from older generations about the past in order to inform their future scenario building. The different sources of information from the past, whether it was differences like rural or urban, poor or rich, immigrant or native, enabled the students to imagine greater possibilities for the future. Importantly, during activities like this, learners must feel they are in a safe space to share this kind of information. This is done partly by educators stating explicitly that diversity is highly valued and important.

All of the modules are trandisciplinary in nature, and students from different academic interest backgrounds participated in them. Transdisciplinarity was perceived as a challenge by the students, so they had to work together and learn from each other in order to participate in the activities. Teachers supported this peer-learning by grouping students intentionally into mixed groups and stating that they should look to each other when they were unsure of something. This underlined the value of diversity in working with complex, trandisciplinary STEM issues.

The inclusive approaches described above contribute to students' perceptions of the learning process as relevant to them because they are invited to relate to the topics and issues in personal and emotional ways and as unique individuals, whose contributions are all needed and valuable. Working throughout the module to develop future-scaffolding skills further supports inclusion because they are not disciplinary-specifc skills, but transverse skills that will be assets in the rapidly changing present and future. Future-scaffolding skills like strategic thinking and planning, risk taking, thinking beyond the realm of possibilities, managing uncertainty, and creative thinking, are inclusive of all students because they are relevant for the future, and not least the future labor market, irrespective of backgrounds and abilities. In this way, an inclusive approach in science education can make a significant contribution to filling the skill gap between school and work. Indeed, these kinds of future-scaffolding skills may be the most important competences for all students to be prepared for any future scenario.

Conclusion

The I SEE project showed the potential for futures orientation, exposure, authenticity, action competence and inclusion to bridge futures thinking to science education to make science teaching and learning relevant to students' futures and STEM careers. The module implementations showed that students changed their perceptions of the future, discovered new possibilities for action and new ways of thinking, and became aspirational for their desirable future scenario. Based on these experiences and results, the I SEE project recommends that policymakers and school leadership prioritize future-oriented scientific issues in curricula and that schools and teachers be given resources and support to become able to work with these issues using effective approaches like the I SEE model. At a time when future uncertainties are threatening, building capacity for adaptation, imagination, innovation, action competence and ethical leadership in young adults has never been more imperative.