O4 – Case studies

It's your time to imagine the futures

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It's your time to imagine the futures

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Case studies-team: G. Tasquier[1], E.K. Palmgren[4], E. Barelli[1], L. Branchetti[1], E. P. Fantini[3], A. Laherto[4], O. Levrini[2], C. Wilson[5]

[1] Team of the University of Bologna, Italy

[2] University of Helsinki, Helsinki, Finland

[3] Liceo "A. Einstein", Rimini, Italy

[4] Landvernd, the Icelandic Environment Association, Iceland

Chapter 1 – Overview

In this document we report the main research-based studies we carried out in order to monitor the impact of the I SEE modules on students' learning and on students' perception of the future.
The case studies have been developed through the analysis of both quantitative and qualitative data collected by means of a multiplicity of tools: questionnaires, individual interviews, collective discussions, tutorials, audio/video records, specific grids and board diaries for observations. The specific tools for data collection have been chosen and designed to cover both individual development and collective dynamics.
In order to guarantee the credibility, reliability and robustness of the data analysis and the results, a detailed description of the whole analytic work will be carried out and documented in this report for each case. Data have been collected during the two-round I SEE module implementations ("start-up I SEE module" O1 and the "I SEE modules" O2). The main results discussed here concern the data collected during the implementation of the start-up I SEE module (O1) in the Summer School (C1). In Chapter 3 we include the results about the analysis of data collected during the implementation of I SEE module on quantum computing (O2) in Finland; moreover, we refer here to the list of these developed at the University of Bologna and the University of Helsinki about the project.
The analysis of the case studies translates into finding a way to not only explain what happens in the implementation of an I SEE module, but also what conditions are needed to overcome obstacles and maximise the probabilities of repeating successful experiences in different contexts. Moreover, the results allow to argue in deep detail what learning outcomes and skills can be developed through the implementation of the I SEE modules and how a teacher can reveal, monitor and evaluate them.
The main results, indeed, of the whole process of investigation has been the list of the markers that can reveal the impact of students' perception of the future (the widening and approaching markers) (see case study #1,2,3) and the markers that operationally define the future-scaffolding skills (see case study #3).
The case studies are the basis for research papers that have been presented in national and international conferences and submitted to journals in science and mathematics education or to journals in the learning sciences. The published papers are reported in the Annexes.

Chapter 2 – The progressive operationalization of the concept of future-scaffolding skills

In this chapter we report the iterative process that led to the operational markers that we pointed out to monitor the impact of the I SEE modules on: a) students' perception of the future (the widening and approaching markers) and b) the development of future-scaffolding skills.

The idea of future-scaffolding skills was born as *sensitizing concept* in a pilot study that the research group of Bologna carried out before the beginning of I SEE. We report this analysis as first case study, since it paved the way for the following investigations. The whole paper, submitted to International Journal of Science Education, is attached as Annex 1. In section 2.1 we sum up the main results.

On the basis of these preliminary results, a second case study was carried out on the data that the research group of Bologna collected during an Italian Summer School where the start-up I SEE module on Climate Change was partially implemented (just after the I SEE international summer school, June 2017). This analysis led to the production of an I SEE reference for the markers that was used to analyse the more complex data that we collected in the international I SEE summer school (June 2017). In Annex 2 we report the paper on the second case study that was selected for the ESERA 2017 special series and that we sum up in section 2.2. In section 2.3 we report the main study we carried out within I SEE where, finally, we were able to operationalize the impact we can expect from the I SEE module (third case study). This study represents, in our opinion, the more original and important research result of I SEE.

2.1 Future-scaffolding skills as sensitizing concept (case study 1)

2.1.1. Implementation description: context, data sources and methods

The first case study concerns the implementation of a teaching module on climate change that has been designed on the basis of design principles that were also applied to the I SEE modules (see Intellectual Output 3). These principles have the role to make science teaching relevant of a scientific, social, vocational and personal point of view, as well as to contribute to developing skills for managing (rationally and emotionally) uncertainty towards the future, and projecting imagination forwards.
The sets of principles that we followed to design the first (pre-I SEE) climate change module are:
Set #1: (1.1) *making the scientific temporal patterns and causal models explicit, by introducing and discussing complex systems concepts in appropriate (physics) curricular moments (for example, when the curriculum includes topics like thermodynamics or climate change)*; (1.2) *enabling students to make direct experience with the language and tools (e.g. simulations) of the science of complex systems and of its societal implications, so as to turn scientific knowledge into skills to talk and think about the future (and, hence, about the present and past).*
Set #2: *integrating the societal and vocational dimensions* (Stuckey et al., 2013) *with the conceptual and epistemological ones in science teaching. This implies, operationally, (2.1) the choice of a future-relevant scientific issue and (2.2) the design of teaching activities aimed at developing special transversal skills: skills helpful to mapping the complexity of the present into a comprehensive picture* and *engaging with the future significance of the issue.*

Set #3: *(3.1) making the learning of science relevant from a personal perspective* (Stuckey et al., 2013). *This operationally implies the enrichment of science teaching with activities aimed at (3.2) developing personal engagement, creativity as well as foresight and anticipation attitude and (3.3) encouraging students to take the agency for their future.*

The module was implemented in 2015, in a grade 12 class of the Scientific Lyceum A. Einstein in Rimini (17-18 years old students). The activities consisted of 7 extra-curricular sessions. The activities were designed solely for volunteer students of the class; 24 (15 females and 9 males) out of 25 students participated in the project.

The implementation was firstly monitored and analysed to give a contribution to the following research question: *Did the module impact students' ways of thinking of the future? If so, how?*

In order to answer this question, several forms of data were collected: a) a pre-test about the perception of the future, constituted of a written essay where students were required to *"Imagine yourself on a spring day in 2030 and imagine how the phenomenon of global warming will have changed the environment around you and the place where you think you will be living"*; b) audio and video recordings of all the sessions and the groups' work; c) the projects made by the students; d) notes by researchers; e) 12 individual semi-structured interviews[3], carried out at the end of the module (Table 2.1).

The written essays and interviews were the richest and most versatile data and we used them to answer the research question.

Table 2.1. Data collection (*Legend of the table: B: beginning of the path; D: during the path; E: at the end of the path*)

MAIN DATA SOURCES	**MOMENT OF SUBMISSION**			**CHECKED ISSUE/DIMENSION**		
	B	**D**	**E**	**CC**	**Imaginary**	**Creativity**
Written essay (about future in 2030)	X	X		X	X	X
Audio and video recordings of the sessions		X				
Researchers notes		X				
Individual semi-structured interviews			X	X	X	X

In order to interpret the results, they have been compared with a Eurobarometer report so as to check if our investigation shows patterns already revealed by large-scale surveys. The Eurobarometer report we considered is entitled Public Opinion on Future Innovations, Science and Technology, Aggregate Report, Eurobarometer Qualitative Study (2015). It presents a survey on the public response to scientific and technological innovations that could be part of the daily lives of European citizens in fifteen years, i.e. in 2030, in four different areas: home and lifestyle; health; communication and relations; environment. The report illustrates the general perceptions of scientific and technological innovations and spontaneous projections regarding tomorrow's society. The study is based on 96 semi-structured discussions ('focus

groups') conducted with small groups of citizens (range 18-64 year old) in 16 EU Member States. The main part of the discussion is dedicated to reactions and discussions of the participants about possible scenarios shaping the future. Disaggregated analyses to point out inconsistencies across age groups, education levels, and different Member States have been carried out. The main result is that the "in overall terms, people expressed similar hopes and concerns for the future in terms of what science and technology will bring – however the extent to which these views affected their overall view did differ." (Eurobarometer, 2015, pp. 7).

Because of the theme and the authoritativeness of the report, we used the results of the Eurobarometer survey for triangulating the ones emerged from our analysis.

The data were analysed through an iterative process that foresaw both bottom-up de-briefing phases, designed to identify the emergent aspects in the data and generate interpretative ideas, as well as top-down phases, aimed at validating interpretative hypotheses formulated by the group of analysts. In order to reach an acceptable level of internal validity, the top-down analysis was conducted through a triangulation process between several researchers in physics education. The triangulation process was carried out by articulating the work in individual analysis phases followed by phases of collective discussion among researchers. This iterative process of multiple triangulations led to a gradual refinement of the categories identified in the analysis.

2.1.2 Main results

The initial picture of the students' view of the future was drawn from the written essays. In the first bottom-up phase of the analysis, three researchers (GT, IV, OL), after an independent reading of students' writings, pointed out three main focal points: the difficulties of several students to imagine a future scenario; the multiplicity of dimensions on which changes are perceived; the variety of attitudes toward the future. The researchers, hence, analysed systematically the data to figure out the initial state, answering the following three sub-questions: a) how many students are able to imagine a future scenario, different from the present one? b) what are the main dimensions of change (technological, environmental, *etc.*) they perceive? C) what attitude do students show toward the future (positive, negative, neutral, *etc.*)?

The analysis led us to identify the students who did not perceive any change and the categories to code the dimensions of change and of attitude. The final categories and the results are reported in Figures 2.1a, 2.1b. In table 2.2 examples of students' answers for each dimension of change are reported.

Table 2.2. Illustrative quote about the dimensions of change.

Environmental
"The increase in the earth's temperature has caused a further melting of the glaciers and [because of] the raising of the water level, the man is trying to adapt to live below sea level and below the rivers." (F14)
Social
"Unfortunately, the relationships between us have changed, we tend to feel more and more by mobile phone and to hide behind a screen." (F18)

Political

"Fifteen years ago, all this seemed unthinkable, like science fiction stuff because of the indifference of international politics that filled the mind of public opinion with false proclamations and ineffective pacts. Now […] climate change sceptics have now changed their minds, as has the international community, which has finally imposed strict limits on greenhouse gas emissions unanimously, especially to eastern industries." (M7)

Technological

- ***Science Fiction:*** *Even if it is a big problem, the solution to the rising sea level will be found. In case entire cities will be submerged and we find ourselves underwater, professionals like architects and engineers will have already thought of a solution: floating cities zero emissions, self-sufficient thanks to energy solar and wind power."* (F16)
- ***Innovative tech:*** *"Houses will be covered with hydrophilic material to remedy extreme weather events, and [there will be] great innovations for transport [like] expensive but efficient low-level flying vehicles."* (F1)
- ***Low tech:*** *"An aspect that I greatly appreciate is the scarce use of electronic objects: due to the intensification of the number and frequency of extreme weather events, it has become difficult to maintain stable lines of communication."* (F4)
- ***Diffusion of existing tech:*** *"The photovoltaic systems will have vastly spread among the population and most of the buildings will have an energetic system based on renewable energies."* (M6)

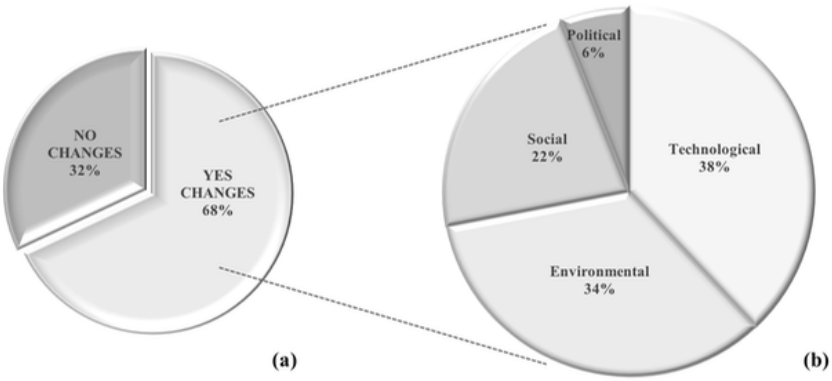

Figure 2.1. (a) Percentage of students who see changes or not in the future; (b) Sectorial breakdown of the changes

The graphs show that almost one third of the students do not expect any change in the coming years (Figure 2.1a), whilst the others perceive change at three main dimensions: environmental, societal and technological (Figure 2.1b).

The relationship with the technological future appears ambivalent and diversified: some students imagine a return to a less technological world, others imagine a widespread expansion of the existing technologies, others predict science fiction scenarios (like underwater cities). Only a few try to think about real innovations. Very few of them describe the future as a stimulating challenge that could allow humans to explore new social and political structures and to develop new technologies (Figure 2.2).

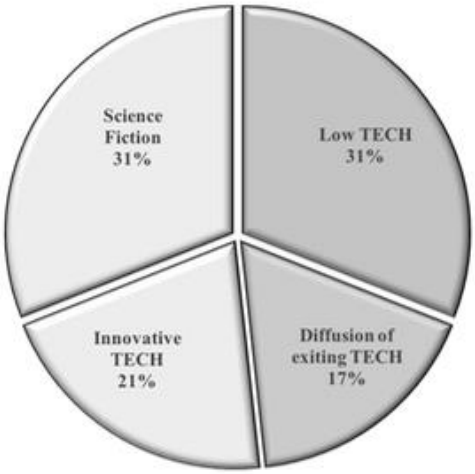

Figure 2.2. Students' relationship with technology

The analysis shows that young people feel, on one hand, the fascination for a constantly evolving world and, on the other, they see technology as cause of several risks, like replacing human beings in social life and in labour market.

This result resonates with the Eurobarometer report, where a similar ambivalent and diversified attitude is observed also among the younger component of the sample. There, the positive impacts are generally related to: efficiency, ease, freedom, comfort, speed, simplicity, modernisation, convenience, improved quality of life and a more environmentally friendly existence. The negative impacts are generally related to: loss of socialisation skills/dehumanisation, data security concerns, unemployment/job losses due to the automation of work, loss of privacy/freedom, social exclusion, pressure to keep up with changes, laziness and deskilling as one forgets how to do certain tasks.

The main difference with our results is that none of our students seems to worry about the violation of privacy, a problem instead stressed by the people interviewed in the Eurobarometer survey. However, although the main results were very similar across the ages, that survey was able to point out that "older people tended to be more concerned about the implications of these advances on data security. Younger people who have grown up in the digital age were just as likely to mention these concerns (more aware perhaps of the implications for data security) but tended to be less concerned about this in general than older people: they were instead more worried about specific (mis)usage of this data." (Eurobarometer, 2015, pp. 8). This result of the Eurobarometer represents a possible explanation of the difference we noticed.

With respect to the students' attitudes toward the future, most of them feel a sense of detachment, fear and anguish. Some students demand influential action from other people (scientists, innovators, policy-

makers); other students show a similar sense of devolution but nuanced as confidence in science and technology. Only a few of them feel optimistic about the adaptability of humans and are curious about the cultural or technological challenges that the future offers (Figure 2.3). In Table 2.3, examples of students' sentences for each category are reported.

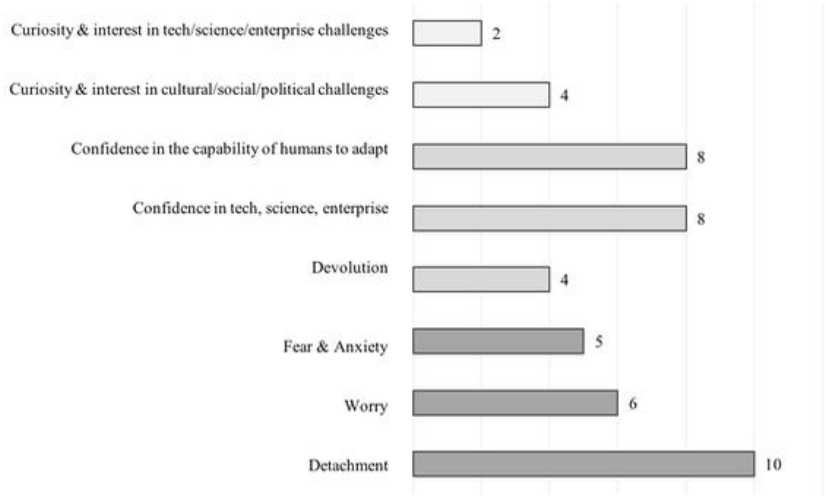

Figure 2.3. Students' attitude toward the future

Table 2.3. Illustrative quote about students' attitudes toward the future

Curiosity & interest in tech/science/enterprise challenges	*"It is exciting to think that we will address big problems thanks to technological innovations, like creating new ways to make water potable or to produce alternative food."* (F15)
Curiosity & interest in cultural/social/political challenges	*"I want to believe that the problems to be fought will be addressed with the awareness of being in 2030 and with the desire to progress, learning from the past. We will live in a cosmopolitan world without cultural barriers."* (F4)
Confidence in the capability of humans to adapt	*"In 2030 the life quality will improve, and man will learn how to adapt to nature, he cannot just command it"* (F14)
Confidence in tech, science, enterprise	*"Science will give its contribution with new analyses and discoveries."* (M6)

Devolution	*"Someone else will find the solution to the problem, even if large […] For example, if entire cities were submerged, the architect would have already thought of a solution." (F16)*
Fear & anxiety	*"The situation [is] increasingly in decline and considering the crisis in which are immersed, I don't think our dreams will ever come true."* (F10)
Worry	*"I am concerned that the insecurities and unpredictability of the climate can trigger psychological problems in people."* (M7)
Detachment	*"I don't see the problem of future's change because I am just a drop in a huge sea and cannot influence the future… everything is so complicated."*

To sum up, the initial picture confirms the trends observed by the Eurobarometer report and shows a widespread feeling of scepticism as well as a tendency to deny the problem and remove the future from their personal horizon.

We constructed the final picture of students' relationship with changes and the future by analysing the post-module interviews, that included questions related to the initial essays. What emerges is, in most cases of the interviewed students, a significantly different relationship. More relevantly, it emerges that the students felt to have developed some skills to build fruitful and structured pictures of the present, characterized by internal relationships between different stakeholders and problems and able to make them feel actively part of the big social and environmental current problems. While their perception of the future was changing, it was also changing the perception of their role in the present.

To unfold these main general results and look for indicators of the impact of the activities, we carried out the second phase of the analysis, articulated on two levels. On one hand, we searched, in students' interviews, for recurrent terms they used to comment on the module or to describe their relation with the future. The aim was to flesh out, from students' words, general trends. On the other, we focused on few students (8) to search inspiration and ideas to grasp what happened during the activities. Specifically, we searched for those students who were able to express in clear and articulate ways what activities did impact their perception and how. The combination of the two levels of analysis allowed us to point out what we consider the main result of the study: a sensitizing concept that seems to have the potential to become a theoretical construct able to describe and interpret the impact of our approach.

The main result of the interviews' analysis is that all the students but one used similar terms to express how the activities impacted their knowledge: the activities are said to have contributed to "widening their perspectives" and "making future become closer". Widening, in students' words, could refer to: (1) the *knowledge they felt to acquire of the topic* (of climate change and related aspects like migration, increase of vulnerability); (2) the range of *possible actions*; (3) the range of *new ways of thinking* and looking at problems, also informed by the concepts of the science of complex systems (e.g., complex patterns of causality); and (4) the *awareness* and confidence in their own potential and their role of agents.

Regarding the future, it was perceived 'closer' in several senses: (1) closer *in time*, in the sense that the year 2030, from far and unimaginable, became thinkable as a set of possibilities; (2) closer *to reality*, in the sense that it became approachable through concrete actions in the present; (3) closer *to themselves*, in the sense that the future became within their reach and they found ways to see themselves as agents of their own future.

In order to show that "widening and approaching" are not student-specific results but emergent trends, we report in Figure 2.4 the frequency of these aspects in students' interviews. All the students but one showed at least three markers of widening or approaching.

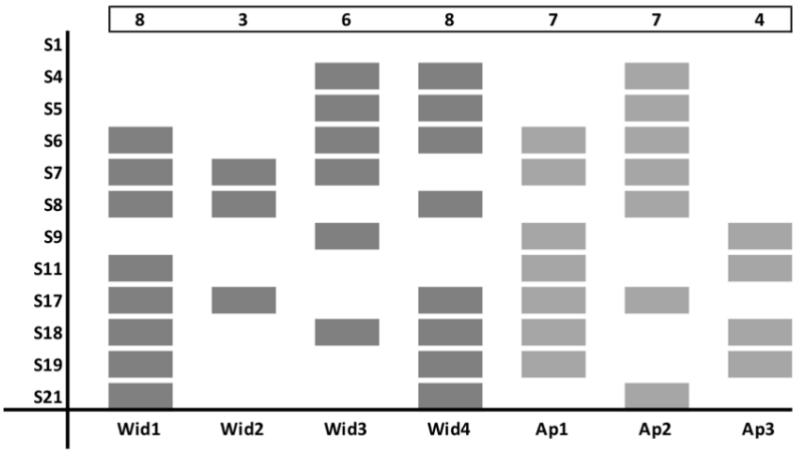

Figure 2.4. Number of students who express the sense of "widening their perspectives" and perceive the "future closer".

In order to search for indications to unfold what happened during the activities we focused on students who provided articulated answers. Here we report and comment on statements by two students: Elena and Sara. Their initial graph positions show that they both imagine a world similar to the present or with a low technology/same technology as now. They desire a return to an imaginary peace of the past since one of them (Elena) feels worried and the other (Sara) feels detached from what will happen in the future.

The first comment is from Elena:

"The project has helped us to think, to do something in relation to something else [...] what I learned about shifting from problems to goals impressed me a lot, it also "woke me up", in the sense that often we perhaps see all the problems and do not see even one positive aspect, with this project we have seen that things are feasible and they depend on how we act, we didn't talk about abstract things. [...] If we are too focused on one thing, we cannot see it in a global context… instead we must always have a vision which is both global and transversal, and then of course, when necessary, we must be able to explore details, but always remember the context in which we are." (Elena)

In this comment, four main aspects are worth stressing:

(1) Elena became able to build up a comprehensive image of the many problems in the present related to climate change, where the various aspects are related to each other, "*something is in relation to*

something else": the present is not yet perceived only in terms of "dust of moving splinters" but as a system in which the components are connected to the others by means of mutual relationships.

(2) Elena confirms that the young tend to perceive the future as overwhelming and bleak "*often we perhaps see all the problems and we do not see even one positive thing",* but thanks to some activities, she did not yet feel stuck because of this feeling. On the contrary, the activities "woke her up" and she saw possibilities and assumed a *planning* attitude instead of renouncing in front of an amount of problems. Elena discovered herself to be a possible agent of her future, because she discovered that many actions are feasible and within her reach: "*with this project we have seen that things are feasible and they depend on how we act".* She moved thus toward a conception of the relationship between future and the present and thinks in terms of possible scenarios that depends on present actions.

(3) For Elena, the key to change was to have a "global and transversal vision", a big picture from which to zoom in on concrete local actions, without getting lost: *"we must always have a vision which is both global and transversal, and then of course, when necessary, we must be able to explore details, but always remember the context in which we are."*

Another very significant comment comes from Sara:

> *"[the activities] have opened my mind and provided many more points of view than I had before. At the beginning, though, [the activities] really demoralized me because I thought I was not able to do it. I thought I did not have a mind that could look forward and see more than I could see before. Instead, through the project, I was really able to reach a point that I previously did not believe my mind could arrive. [...] The project changed my way of thinking, not only for me but also for the others." (Sara)*

Also, in this comment, several aspects are worth stressing:

(1) Sara mentions an initial sense of frustration *"At the beginning, the activities really demoralized me because I thought, I was not able to do it"*, but she recognises that the activities "opened my [her] mind" and, mainly, "opened many points of view", a set of possibilities to look forward to. She feels she had developed new skills and that something changed (at the beginning, she did not feel to be able to find a project idea). She started to adopt a way of thinking in terms of possibilities and this allowed her to overcome the feeling of frustration: this way of thinking, hence, acted for her as a scaffolding factor. Also, she discovered potential skills that she did not believe she had: "*through the project, I was really able to reach a point I previously did not believe my mind could arrive*".

(2) For Sara, the key moment was the activity on project design, which obliged her to face a real challenge and, by providing her with the necessary support to be successful, enhanced her self-confidence and *"changed"* her *"way of thinking"*;

(3) Sara was able to notice changes also in her classmates: "*The project changed my way of thinking, not only for me also for the others"*.

The two cases of Elena and Sara are not representative of all the students. However, they represent a rich source of insightful ideas inasmuch as, in their words, it is possible to recognise the potential of the approach to develop very important skills.

The analysis of the final interviews made some global trends emerge: the approach seems to be effective in impacting on students' future perception in terms of "widening and approaching".

Additionally, the analysis of the cases of Elena and Sara pointed out that the approach appeared promising to develop specific skills to structure ways of thinking about the present, the futures and their back and forth-relations.

The emergence of this bunch of skills is the birth of what we called, afterword, *future-scaffolding skills: skills* that refer to the capability of organizing knowledge in the present, imagining futures and moving dynamically and consciously, back and forth, globally-locally, between different time dimensions. Thanks to their emergence, this pilot study led to the identification of a *sensitizing concept*, that is a concept that has the potential to theoretically orient the following studies and can be progressively tested, developed and refined as theoretical construct (Glaser & Strauss, 1967). This is what we did in the following two case studies.

However, this analysis shows that students developed these *future-scaffolding skills,* since their ways of reasoning about present and future resulted to be enriched with: i) the logic of *causality* (recognize cause-effect relationship and build causal maps; distinguish between linear and circular causality, recognize feedback loops); ii) the logic of *uncertainty* (the difference between projection and prediction); iii) the logic of *possibilities* (the difference between plausible, probable and possible scenarios); iv) the logic of *multidimensional, multi-perspective and values-based problems analysis* (how to formulate a complex problem concerning the future; who is involved in decisions and who are the stakeholders); v) the logic of *action* (how we can concretely contribute to fostering a desirable future). Students found the opportunity to enrich their thinking with the logic of causality, uncertainty and possibilities, thanks to the sessions designed to implement the first set of principles, where scientific contents were reconstructed so as to flesh out the causal models and where concepts of the science of complex systems were discussed. These aspects were then strengthened during the "present-focused sessions" of project planning part of the module, where the construction of the problem tree and its transformation into an objective tree represented the core activity that bridged content-based sessions with the future-oriented part of the module. This part was fundamental to expose students to the logic of *multidimensional, multi-perspective and values-based problems analysis* and to the logic of *action.*

2.2 Toward a first individuation of future scaffolding skills (case study 2)

2.2.1 Implementation description: context, data sources and methods

The second implementation concerns a module on Climate change that represented a combination between the module designed by the research group of Bologna and the I SEE start up module (O1). We enriched the conceptual and epistemological part with the future-oriented activities that we designed for the I SEE module. The implementation was carried out at the Department of Physics and Astronomy of Bologna in June 2017. It involved a group of 39 students 17-18 years old (16 females and 23 males) from different high schools.

The summer school represented an extra-school activity in which students were selected on voluntary basis. The summer school lasted 5 days (6-8 hours per day). Before, during, and after the implementation, we collected the following data: written essays, questionnaires, audio and video recording of the activities, researchers' notes, and students' projects.

The research questions that oriented the data collection and analysis came from the previous study. They are:

RQ1 What kind of effects did the module have on students' perception of time (both present and future)? Are such effects comparable/compatible with the empirical preliminary results we achieved in the pilot study?

RQ2 What contribution does the study offer to the definition of future-scaffolding skills?

In order to answer the RQ1, we used the same pre/post test approach as in the first case study. In particular we applied the same tool (a written essay where students were required to "Imagine yourself on a spring day in 2030 and imagine how the phenomenon of global warming may have changed the environment around you and the place where you think you will live") to collect data about students' perceptions of the future before teaching and a comparable final questionnaire. In the final questionnaire, we included two questions, general enough to leave the students free to answer as they wished, but also focused enough on the perceptions of present and future to check the results of the pilot study and to confirm/discuss them (Table 2.4).

Table 2.4**.** Questions from the post-questionnaire.

Qa	*Did the summer school give you the tools to face the present? If so, please explain in a few words in what way this is true.*
Qb	*Did the summer school give you the tools to face the future? If so, please explain in a few words in what way this is true.*

The other data we collected (audio and video recordings of all the meetings and group work; the projects designed by the students; notes of researchers) have been used to triangulate the analysis of the pre/post tests and to monitor the overall process.

To answer RQ1, the data have been analysed through the same semi-qualitative methodology of data analysis that we used in the first study.

In order to answer the second research question (RQ2), we looked at the data through a qualitative lens designed to recognize eventual patterns of "scaffolding signals". We applied the researchers' triangulation, practice reflexivity as well as member-checking (with all the participants of the study, i.e. teachers, students, and researchers) (Anfara et al. 2002), to highlight not only what happens in a specific teaching/learning experience but also to search for an interpretation of why, when and how it happened (Cobb et al. 2003).

2.2.2 Main results

The first thing we analysed was how many students perceived changes in the future: 87% of students described their future by highlighting changes with respect to the present. Out of the remaining 13%, 23% drew pictures similar to the present and the others were not able to imagine or describe a future scenario. This distribution shows, like in the Eurobarometer (2015), the presence of students who are not able to imagine the world differently. In our pilot study, this fraction was almost one third.

In Figure 2.5 we report the dimensions of change that the students who perceived a future different from the present used to describe their scenario in the essays. A bottom-up process of analysis led us to recognise the same dimensions that the students used for describing 2030 scenarios in the pilot phase: environmental (25), technological (30), social (7) with a specificity about health (4) and political (2).

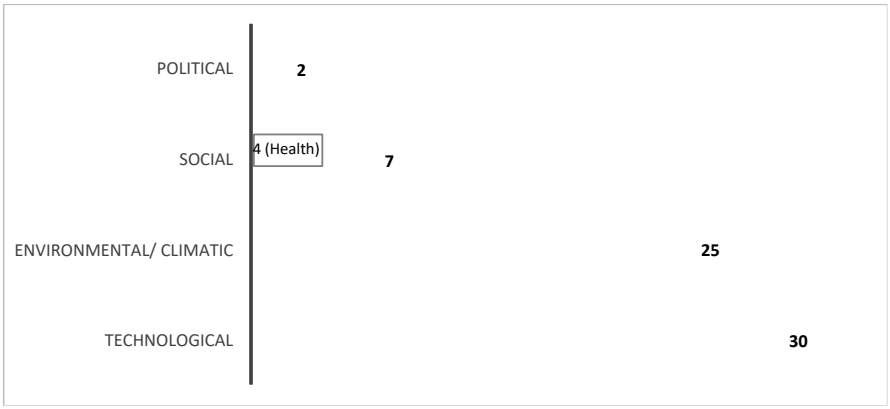

Figure 2.5. Dimensions of change in the descriptions of students' 2030 scenarios.

As for the environmental dimension, students highlighted changes in the surrounding environment mostly at a level of climatic consequences. Generally, a vision of revolutionary change is not prevailing but there is intensification of aspects already traceable, like rising sea levels or floods or waves of drought, desertification (for the negative views), or like the mitigation of climate problems thanks to a decisive emissions reduction and the extension of parks and green areas (for the positive views).

The political dimension is very infrequent in the essays. The two students who talked about it stressed: the importance of political and economic choices to govern climate changes and make this world more eco-friendly; worry about future demagogic policies, and the fear that people are not able to develop a critical consciousness.

The social dimension appears more frequently than the political aspect, but generally it is centred on the problem of how social media and new technologies can change human relationships. Within this dimension the problem of health was mentioned by four students. It was absent in our pilot study, whilst it is a relevant point in the Eurobarometer survey.

As in the first case study, the technological dimension was definitely the most diversified and frequently-mentioned by the students. Students' descriptions of 2030 range from science-fiction perspectives (5) to low-tech worlds (10), passing through scenarios where already-existing technologies are more widespread (14) or new technological innovations are produced (5) (Figure 2.6).

Figure 2.6. Relation with technologies.

This distribution highlights a well-known and substantial fact, stressed by the Eurobarometer and already pointed out in our first case study: the ambivalent relationship of the young with technology, torn between desire for a life that increasingly benefits from technological developments and a sense of nostalgia toward an idealized low-tech past, especially as regards human relationships.

Another very well-known trend that is also confirmed by these data is the negative and pessimistic attitude towards the future, as well as the tendency to deny or delegate the problem to other people (scientists, innovators, policy-makers). Figure 2.7 shows students' attitudes towards the future where it emerged that, as in the pilot study, very few of them (5) described the future as a stimulating challenge that could allow humans to explore new social and political structures and to develop new technologies (*"All these problems, however, will be opportunities to develop new technologies. If these problems can be exploited, scientists can make new discoveries and achieve great results"*), whilst many (25) express fear and anxiety (*"I fear that these policies that focus purely on economic profit and carelessness of environmental health could lead to terrible consequences"*), and a significant number (11) delegates or trusts that someone else or human adaptability can address the problems (*"My family and I are aware that we cannot do much to improve this dramatic situation, as the big change should have already been implemented at the political level."*).

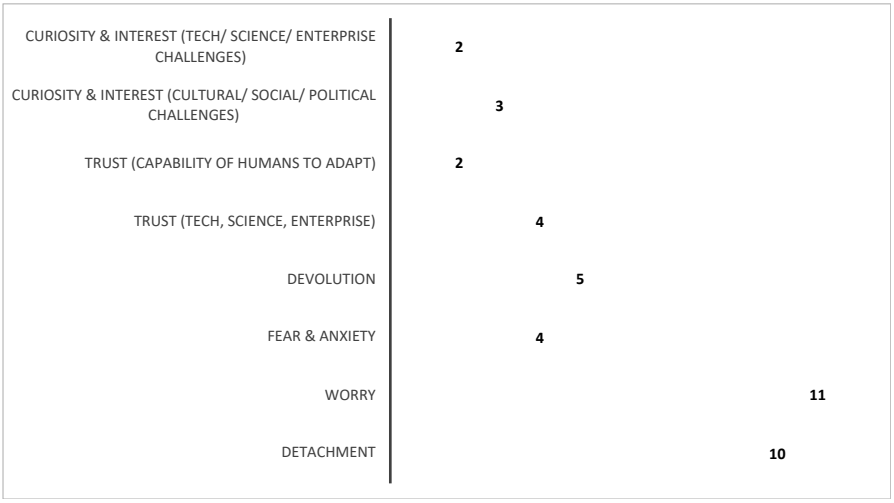

Figure 2.7. Students' attitudes toward the future.

To sum up, the analysis shows that the sample of this study has an initial view of the future that is comparable with the preliminary picture held by students involved in the pilot-study (Levrini et al. 2018). This picture confirms the widespread negative and pessimistic feeling towards the future as well as the tendency to deny the problem and/or remove the future from their personal horizon. From a methodological point of view, this analysis allows us to state that the two samples were comparable for the initial picture of the future.

The final picture of students' views was constructed by analysing students' answers to the open-ended questions of the post-questionnaires reported in Table 2.4.

From students' answers to Qa (*Did the summer school give you the tools to face the present? If so, please explain in a few words in what way this is true.*), an awareness emerged very often about the relevance of thinking about the present and that something happened in their perception: *"the summer school taught me to be more effective and efficient in analysing problems […] I understood that the analysis of the present is very important, above all as a basis for changing the future (S26)"*.

In their answers, 31 out of 39 students mentioned the activities on text analysis and map building as key sources of tools to deal with the present (see Figure 2.8). We aggregate these markers and we identified them as skills that help the students to face the present (noted as PS).

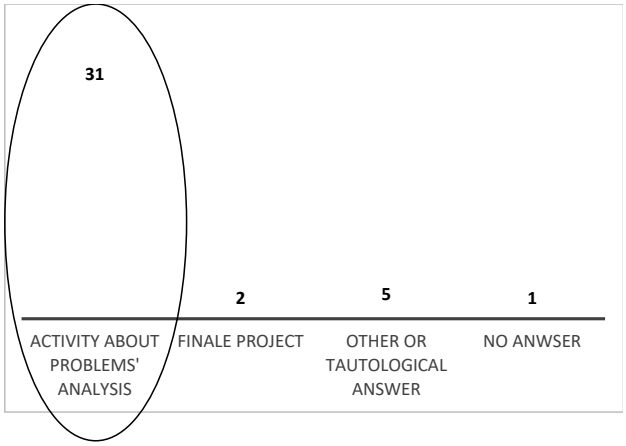

Figure 2.8. Activities mentioned by the students.

Students' answers were rich enough to allow us also to figure out what skills they believed to have acquired to face the present (Table 2). Some students stressed the feeling that they learnt to recognise and select important details and facts from a previously confused ocean of information (PS1). Others highlighted that they learnt to break down a big problem into smaller problems (PS2) and to organize and hierarchize them (PS3). Many students found relevant the way they learnt to organize the problems within a network of cause and consequences (PS4); other students stressed the importance of carrying out an accurate and deep analysis before making any decision and identifying solutions (PS5). Finally, others focused on the importance of distinguishing between problems, objectives and solutions (PS6). Table 2.5 shows the different aspects mentioned by the students with some descriptive categorizations for each of the aspects, while in Figure 2.9 the distribution of the students (x-axis) over the different aspects (y-axis) is reported.

Table 2.5. Skills that the students perceive they have learnt to face the present (PS)

(PS1) Selection or focus on pieces of information	The summer school taught me how to get a lot of different information from a text. Now I can pay more attention to the details that, before this experience, I took for granted or thought were not important. (S3)
(PS2) Breaking down a big problem into smaller problems	The summer school taught me to analyse the problem by breaking it down into problems [...]. (S20)
(PS3) Organize and/or hierarchize problems and information	Through the summer school I learned to analyse problems better, organizing them clearly in maps and hierarchizing them. […] (S22)
(PS4) See a problem in a network of causes and consequences connected to it	The summer school has provided me with a new way of seeing the same situation from different points of view in order to understand it better, to understand the various causes that compose it and the consequences it could have. (S7)
(PS5) Anticipate the analysis with respect to the solution	The summer school taught me how to start from the problems and analyse them in depth before arriving at the formulation of possible solutions. (S8)
(PS6) Distinguish between problems, objectives and solutions	Thanks to the summer school I developed a discrete process of analysing the problems of the present, in particular, analysing the initial problem and its "subproblems", then identify the general and specific objectives and finally identify possible solutions for the objectives. (S27)

Several students stress more than one aspect, as the following examples show:

*"The summer school taught me to analyse the problem by breaking it down into problems (**PS2**) and finding a cause-effect relationship (**PS4**) in order to organize these problems in a hierarchical way (**PS3**). (S20)"*

*"At the beginning I had a lot of difficulty in finding solutions to problems that were difficult to identify (**PS1**). By comparing ideas with others and spending a lot of time on a problem to try to analyse it and break it down (**PS2**), in the end I managed to identify many problems and solutions (**PS6**). (S2)"*

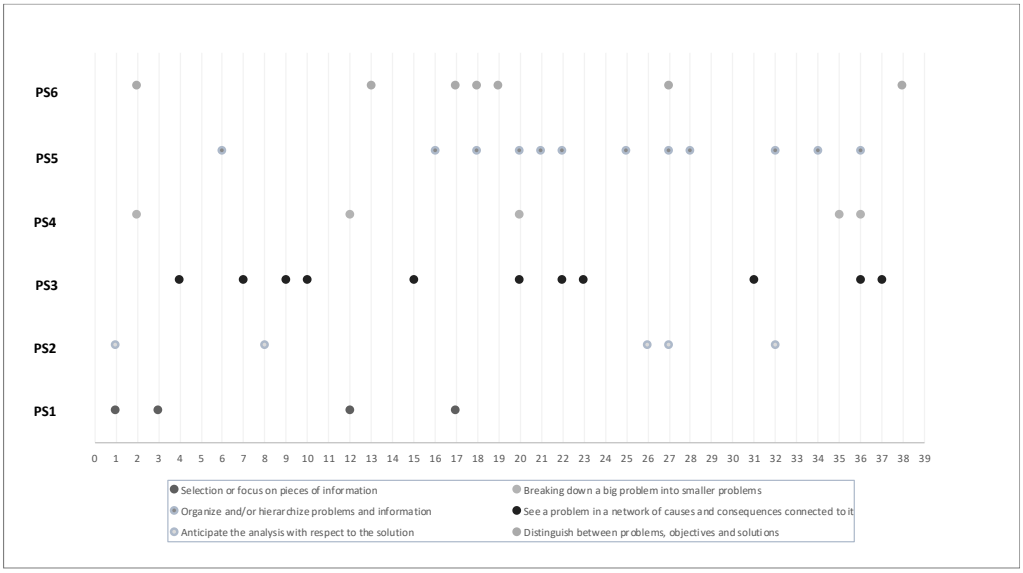

Figure 2.9. Students' distribution along skills they have learnt to face the present (*x-axis:* the 39 students who participated in the summer school; *y-axis:* skills described in Table 2.5).

The first finding of our analysis is that these data confirm what we discovered in the pilot study, i.e. some activities revealed the potential to impact students' perception of the present. More than in the first

case study, it emerged that the activities encouraged students to *consciously* develop special skills. We find it very interesting that all the skills they describe are *structural*, i.e. skills that serve to organize the impelling, fragmented and chaotic reality of present from selecting pieces of information among the indistinguishability of the background (PS1), to organise pieces of information into relations that can be hierarchical (PS2), causal (PS3), temporal (PS4) as well as to distinguish logical codified structure of reasoning among them (PS6).

In order to check whether students' reactions on the future were comparable with the reactions we encountered in the first case study, we analysed the answers to Qb (*Did the summer school give you the tools to face the future? If so, please explain in a few words in what way this is true*) in two ways: first we carried out top-down analysis by applying the markers we bootstrapped from the data of the first study and then we carried out a bottom-up analysis to check the validity of the markers for this study and if with these markers we reached a level of saturation. Figure 2.10 reports the results of the analysis. The graphic shows the high frequency of these markers in students' comments and the introduction of a new marker. In Table 2.6 we illustrate the markers by giving a refined definition as a result of the combined process of analysis, by reporting examples of how students directly describe the impact of the activities on their perception of future.

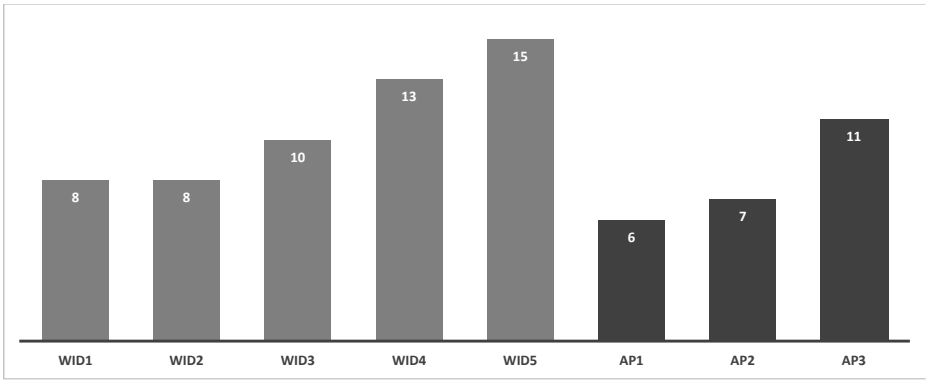

Figure 2.10. Frequency of the markers in students' words.

Table 2.6. Description of the markers by using examples of students' expressions.

(Wid1) widening in their knowledge of the topic (of climate change and related aspects like migration, increase of vulnerability)	The explanation of the CC problem has heightened my awareness of the threat it poses to humanity and the whole world. My awareness of the loss of biodiversity and the increase of extreme phenomena has increased, thus pushing me to think more about this problem and to discuss it at home, with friends and in various contexts to find solutions together (S22)
(Wid2) widening in the range of new ways of thinking, approaching and looking at the problem	The summer school has led me to think more widely about the future, that is, to take into consideration many different aspects; at the same time, it made me take a more narrow and focused view, that is, only to think of a small situation and analyse that, projected into the future. (S12) He made me understand that to discover new things, you have to take your feet off the ground and try not to limit your imagination. (S7)
(Wid3) widening in the awareness and confidence in the role of citizens and individuals	One goal that I think I have achieved this week is the ability to observe and understand the present and then be able to project into the future. This is also the basic message for acting as eco-sustainable citizens: there is no future without a

	present. The course further developed my awareness as a citizen, also pushing me to the dissemination of these themes. (S21) Surely thanks to this summer school I have understood how I can contribute to improve the environment around us and in the future, I will do my best to work in this area and improve living conditions. (S2)
(Wid4) widening in the range of possible actions, strategies and concrete solutions that can be undertaken	In the initial essay I had thought about how the world could become and not how I wanted it. After this summer school, I realized that if we continue to treat our world like that, it will only get worse, but at the same time I am more serene because I have seen that there are many things that are being done and that I did not imagine existed. (S12) The summer school has certainly made me discover new possibilities, new perspectives and new ways of intervening. (S23)
(Wid5) widening in the awareness and confidence toward research, technologies and experts in the field	Honestly, I feel more confident now that I have met several people working to fight the CC and now that I have seen some strategies in place to combat the phenomenon. (S18) Initially I was afraid there were no technologies and research ideas to change and influence the future, now I understand instead that they are present. (S26)
(Ap1) closer in time, in the sense that the year 2030, from far and unimaginable, became thinkable as a set of possibilities	The school certainly made me discover new possibilities, new perspectives and new ways of intervening. The world I had described in the initial essay was quite utopian and therefore I did not consider it feasible. But now I think we could approach this future and it can be achievable (S23)
(Ap2) closer to reality, in the sense that it became approachable through concrete actions in the present	I understood that the means to change the future are already present, we need to analyse a way to apply them and then change the future. I also understood that the change that must take place in the future to allow human survival is now extremely concrete. I believe the future is scientifically and technically more feasible and approachable (S26)
(Ap3) closer to themselves, in the sense that the future became within their reach and they found ways to see themselves as agents of their own future	Now I can imagine a more positive future than before. I consider it even more achievable because in these weeks I have gained more hope in the future. The creation of the project helped me to understand that thanks to our actions in the present the future can be better and, in this way, I have eradicated my fears (S24)

Both the frequency and the words used by the students confirm what we already observed in the first case study but also add a new nuance in the markers of widening (Wid5) that we did not observe in the first study. We interpreted the emergence of this new pattern as the result of the introduction of the panel with experts within the module. Indeed, the panel was very appreciated by the students since it opened their imagination on research and technological areas and allowed them to see possible STEM-related professions that they did not know.

Concerning the issue of the impact of the activities on students' future scaffolding skills development, some students highlighted that the activities on project design fostered the development of other skills, which we can call *dynamical* skills and that we identified transversally in the students' answers. We grouped them in five preliminary categories, to be clarified in future experiments. They appear *dynamical* since they refer to *back-and-forth processes* of: i) thinking big and thinking small, ii) thinking in the present and thinking in the future, iii) acting as an individual and as a society, iv) imagining new possibilities and planning concrete actions, v) desiring and keeping feet on the ground. We do not have enough data to check this hypothesis, but we believe it feasible that the activities enabling students to expand their horizons and perspectives (Wid1-Wid5) and sense the future as more approachable (Ap1-Ap3) and also have the potential to develop

those specific dynamical skills. *Vice versa*, in the future implementation we will make an effort to refine the activities to engage students more explicitly in these dynamics. Indeed, we consider the discovery of this type of skill a new result, particularly important for responding to our second research question: the study contributes to the definition and recognition of *future-scaffolding skills* by offering two new sets of skills that enable students "to construct visions of the future that support possible ways of acting in the present with one's eye on the horizon" (Levrini et al. 2018); these sets include *structural skills* needed to build comprehensive pictures of the present and *dynamical skills* needed to perceive the future actively and use it to widen the imagination and, contextually, make decisions in the present.

This framework of markers about widening and approaching and about structural and dynamical skills represented out research-based tool to analyse the complex data that we collected in the I SEE summer school and that allowed us to build an operational definition of future-scaffolding skills.

2.3 Operational definition of future-scaffolding skills (case study 3)

2.3.1 Context

This third case study concerns the implementation of the I SEE start-up module on Climate Change (O1) within the I SEE international summer school. The module was co-designed by the partners and implemented by several teachers (two or three per each Country).

The summer school was held in Bologna, June 5-9, 2017 at Opificio Golinelli and the module was implemented according to the following schedule:

a) plenary lectures (encountering activities): 3 hours (Monday morning);
b) Conceptual, Epistemological and Inquiry activities: 8 hours (Monday afternoon and Tuesday morning), led by the Finnish team;
c) Bridge activities: 8 hours (Wednesday morning and afternoon), led by the Italian team;
d) Exposure, future-oriented and action competence activities: 12 hours, including students' presentations (Thursday morning and afternoon and Friday morning), led by the Icelandic team.

The participants to the summer school were 24 students (16-19 years old): 8 from each partnering school, the Normal Lyceum of Helsinki, the Lyceum A. Einstein in Rimini and the Hamrahlid College on Reykjavik. The students were selected by the teachers involved in the project, according to the same criteria, shared in the partnership, and the same method. The students of the proper grade received an application form to fill in in case of interest. The form included a description of the summer school ("A creative summer school workshop for about 25 students (16-19 years) from Finland, Iceland and Italy, with opportunities to develop your 'future scaffolding skills' including strategic thinking and planning, risk taking, thinking beyond the realms of possibilities, action competence, and managing uncertainty – around solving some of the many issues concerning climate change. During the workshop, your feedback on the different activities will help the project team to improve and refine these activities for other young people to work with in the future. The team will also be interested to know what you gained from taking part, and the extent to which the summer school workshop met your expectations") and the specific claim that we were not searching for "STEM persons" ("We would like to bring together students with different interests, perspectives and attitudes towards STEM subjects. Not everyone in the group will be considering STEM as a career option.")

On the basis of the filled in forms that the teachers received, 8 students were selected according to the criterion to have inner heterogeneous groups with respect to gender, school performance in general and in science in particular, cultural background and competence in English.

In spite of the same criteria of selection, a rather substantial difference was introduced by the fact that the students from Helsinki Normal Lyceum have many opportunities to have summer experiences abroad and, unlike the Italian and Icelandic cases, it was not easy for the teachers to find 8 students interested in the summer school.

As a result, the sample was formed by:

- 8 Finnish students, among which 4 females and 4 males, 3 strongly interested in STEM and 5 not particularly interested;
- 8 Icelandic students, among which 5 females and 3 males, XX strongly interested in STEM and YY not particularly interested;
- 8 Italian students, among which 4 females and 4 males, 4 strongly interested in STEM and 4 not particularly interested.

As well as the cultural differences among the three groups, the whole group included students with a rich and diversified cultural background. At last six students, as well as speaking English, were perfectly bilingual because of the different language spoked by one or both the parents.

2.3.2 Methods of data collection and analysis

Inspired by the Design-Based Research and its theoretical orientation we collected data to be qualitatively analysed. In particular, we gathered data to cover four dimensions: conceptual, epistemological, future-oriented and action competence. Data were collected through a large variety of tools (e.g. focus groups, individual interviews, questionnaires, written essays, audio/video-recording of several discussions and activities) for checking one another, for corroborating evidence and for evaluating the extent to which all evidence converges (Anfara et al., 2002).

As already mentioned, the data analysis stemmed from what emerged in the two previous case studies. In those contexts, the students described their experience as a process that led them to *widen* their views about the future and to feel the future as more *approachable*; moreover, they mentioned structural /systemic and dynamic skills that, in our view, appeared good candidate to be operationalized as future-scaffolding skills.

Hence, we decided to use the background evidences (the markers we already had) as *lenses* to read and analyse the data. In other words we decided to analyse this new data set to check if and how phenomena of widening and approaching and structural /systemic and dynamic skills development were visible also in this new context and, if so, what further inferences can be done on the impact of the module on students' perception of the future and the development of skills. To this purpose, we articulated the data analysis in the following phases.

Phase one: data organization and top-down analysis

The first phase concerned the construction of our database, by organizing all the sentences coming from all the data sources, where the students described the effect of the module on their future perception and on their skills development. The goal was to check if the previously defined phenomena of widening and approaching appear also in these data and if they are effective to describe the change of students' perception of future. This methodologically meant to carry out a top-down analysis where the possibility of further bottom-up evidences was left open and inquired.

More specifically, the whole data corpus was organized into a unique Excel table structured, along the rows, in data sources, countries, names of the students and, along the columns, in categories pointed out in the previous study (widening, approaching, structural skills and dynamical skills). A free column was left for a bottom-up exploration and, hence, for collecting all the sentences that could not be coded according to the top-down categories.

As we will describe more in detail in the section about the results, this first phase gave positive results: students' words and whole sentences relatable to widening and approaching were frequent and easy to be recognized. Moreover, the widening and approaching categories captured the main aspects of the change of students' perception of future and none further significant category was identified. We just noticed students' need to express that, through the activities, their sense of hope toward the future increased.

The organization of the data according to the structural and dynamical categories was less easy but appeared sensible.

However, in the triangulation among researchers and in our de-briefing about the table, some criticalities come out in the coding and, in particular, in the definition of widening, approaching and skills markers. In particular, the triangulation pointed out the presence of:

a) redundancies - widenings and some approachings categories tended to overlap;
b) obscurities - different researchers gave different interpretations to the same category;
c) operational ineffectiveness of categories description - the descriptions of the categories did not seem always adequate to point out operational markers, that is markers to guide a researcher to read out, analyse and select the data that can belong to the various categories. As a result of such inadequacy researchers were not able to understand why another researcher codified the data in that way.

Phase two: Revision and reformulation of the categories and of their markers

The second phase concerned the revision and reformulation of the categories, as well as a refinement of the database, according with the new markers. This phase led to the first important result we will report and discuss in the next section: the list of categories and operational markers not only able to code the whole corpus of data but also to capture the main reactions of the students to an I SEE module. This result is

particularly relevant from a theoretical point of view since it does not only provide a list of future-scaffolding skills, but also the operational tools to recognize them in students' discourses or actions.

Phase three: Data reduction and analysis

The third phase concerns the construction of graphs to reduce the data and allowed us to see, in an aggregate form, patterns or emergent properties. In order to interpret the graphs, two research workshops have been carried out. In the workshops, the involved researchers (the authors of the paper and further teacher-researcher involved in the I SEE project) had to describe what they saw in the graphs. All the comments have been discussed and the most relevant have been selected. The sensibility and reliability of the comments has been checked in two different respects: a) they were evaluated reliable if they could be supported also on the basis of arguments coming from other external contexts and sources, b) they were evaluated sensible as they were effective to capture and give back what the observers (teachers and researchers) perceived in the air during the summer school.

This third phase led to another important result: an aggregate picture of students' perception of future and a distribution of the skills perceived by the students.

From this analysis, two comments can be anticipated since they opened up two problems that we addressed in the fourth phase of the analysis.

The first comment regards the graphs about the skills. Because of the data they refer, the graphs just give back a picture of what the students perceived and explicitly claimed during the summer school. They do not say anything about the real development of those skills. Thus, a second important question is: are we able to check if the skills perceived and claimed by the students are real skills they developed? If so, how?

This second comment refers to the evidence that no significant cultural differences can be observed at this level of analysis. The distributions over the three groups are rather similar. This means that the sample was somehow homogeneous (the students had a comparable background) and the module revealed to be diversity-responsive (students with different cultural approaches reacted in similar ways to issues about futures and climate changes). However, since during the summer school the cultural differences were deep and significant, an unsolved open question remained: at what level did the cultural differences mainly appeared?

Phase four: Addressing the open questions

The fourth phase is articulated in two parts, each of them aimed to address one of the previously described open issues.

In order to address the issues about the reliability of the skills perceived by the students, we decided to consider the videos of the final products and to sort out the skills that emerge from students' actions and discourses. We selected two emblematic cases and, after the video-analysis, we could compare the skills that were put in action by the groups and the skills that the members of the groups had previously claimed.

The comparison of these two independent analyses is maybe the most important result we obtained and provides a significant support to claim about the efficiency of the module in really impacting students' development of future-scaffolding skills.

In order to address the cultural differences issue, we decided to go back in the data and search for how they appeared. As we will comment in the next section, we discovered that the main differences concern the educational traditions and the styles of learning and teaching that emerged during the summer school and that the students' experiences in very different ways.

2.3.3 Data analysis and results

Result #1 – The categories and the operational definition of future-scaffolding skills

The first result of the analysis concerns the most relevant aspect of this analysis: the refinement of the markers that allow to reveal, monitor and evaluate the impact of an I SEE module on students' perception of the future and on the development of future-scaffolding skills.

In particular, the analysis led us to recognise that, through the module, the students widened their knowledge and their awareness of the range of possible ways of thinking, roles of stakeholders, actions to address the future-oriented scientific issue (in the case of the summer school, the issue of climate change). Moreover, they ended to perceive future approaching themselves, since it became closer to their imagination, their present and their growth path. In particular, we recognized six different nuances of widening and three of future approaching, which operative descriptions are reported in Table 2.7, each of them flanked by an example of students' sentences. With respect to the table of widening expressed in 2.2.2, the most significant change consists in having distinguished between the widening in disciplinary STEM knowledge about the issue (Wid0) and in the amount of knowledge on future thinking (Wid1). We decided to name the first widening as Wid0 since it does not explicitly refer to a change in future perception but rather to a change in the amount of students' disciplinary STEM knowledge. The definitions are "operational" since their description includes specific markers to code the data and point out if students' discourse presents them.

Table 2.7. Operative description of the markers for the change of future perception by using examples of students' expressions.

Widening	**(Wid0) Widening in the amount of knowledge about the disciplinary contents of the FoSI (Future-oriented Scientific Issue)**	The summer school made me better understand what we are talking about when discussing about climate change, what the problems actually are. (SM23)
	(Wid1) Widening in the amount of knowledge on future thinking, provided by futures studies	The lecture made me know a working field I had never seen before. I understood how forecasts can help out with your career and life in general. (SM23)
	(Wid2) Widening in the range of new ways of addressing and looking at the FoSI	I've learned that the future is complex, and it has to be viewed from many points of view. I've learned to look at every topic from many different viewpoints and to think of many solutions for the future. This is something that is not taught at school that much, in my opinion. (SF4)

	(Wid3) Widening in the range of possible roles of non-expert stakeholders (e.g. citizens, policy-makers) for addressing the FoSI	I found quite interesting that we have always to take into account that global conditions affect local conditions, so everyone has to take care of the world development. (SF19)
	(Wid4) Widening in the range of possible roles of expert stakeholders (STEM researchers and other experts in the field) for addressing the FoSI	You do not usually hear much about people who are active in environmental research. Now I know there are people working to improve this situation. (SF17)
	(Wid5) Widening in the range of possible actions, strategies and concrete solutions that can be undertaken to address the FoSI	I've gotten to learn about some solutions I hadn't heard of before, for example I didn't know biofuel was an option. (SM9)
Approaching	**(Ap1) The future became closer to students' imagination, i.e. from far and unimaginable, it became thinkable to them**	I plan to use my knowledge to plan my future better and expect the unexpected. (SM9)
	(Ap2) The future became closer to students' present reality, i.e. it became approachable through concrete actions that can be undertaken in the present	I'm interested in taking action to protect the environment. For example, I'd like to minimise the amount of food waste. (SF4)
	(Ap3) The future became closer to students' personal, social, professional growth path, i.e. it became within their reach and they found ways to see themselves as agents of their own future	I go home with a reinforced will to continue my scientific studies until graduating as an environmental researcher and by carrying on environmental issues in order to make a change in this world. (SF17)

The second very important result is the identification of skills that we organised in two macro-categories: *systemic-structural* skills (St), which are abilities to *organise pieces of knowledge and build systemic views* (an intentional and conscious process of scaffolding); *non–linear dynamical* skills (Dyn), which are abilities to navigate across the complexity of knowledge, without trivialising the relations between local details and global views, the relations between past-present-future, and the role of individual and collective actions. In Table 2.8, we report the description of future-scaffolding skills markers flanked by examples of students' expressions where they describe the competences they perceive to have gained.

Table 2.8. Operative description of the markers for the future-scaffolding skills by using examples of students' expressions.

Systemic-structural	**(St1) Distinguish between disciplinary details and the comprehensive picture of the FoSI**	Each experiment added a piece of knowledge that at the end of the path of the experimentation occurred to recreate the complete picture of the situation. (SF17)
	(St2) Unpack the FoSI in simpler, addressable parts	I have learned that if you want to achieve something it is good to divide it [the task] in smaller pieces. (SM1)

	(St3) Recognise causal relationships	I found helpful these activities […] because they made me understand suddenly the reasons beyond the feedback process. The biofuel activity in my opinion really worked because we got into the process that involved considering the consequences in the future as the main task. (SF19)
	(St4) Recognize multiple aspects of the problems and their relationships (e.g. distinction between problems, objectives, solutions or between pros and cons) for structuring proper thoughts and articulate strategies and plans for solving them	We can improve our lifestyle or whatever surrounds us starting from what the problem is (global warming, higher temperatures, emissions etc.) and then passing to what could be the solutions, also seeing that many of these that are currently taken as solutions do not have many positive aspects, such as biofuels. And then from all this we could give our idea of a perfect world. (SM23)
Non-linear dynamical skills	**(Dyn1) Move from thinking locally to thinking globally (and vice versa)**	We really need to think globally, even though we start with ourselves and our cities, our countries. (SF15) We should always take into account that global conditions affect local conditions, so everyone should care about the whole world development. (SF19)
	(Dyn2) Move from thinking at the present to thinking at the future (and vice versa)	In the future, but starting from now, we will make a choice about what kind of society and cities we want to live […] Be careful with alternative fuels or other kinds of natural energy sources: look at their impact on the environment as further in time as you can. (SM23)
	(Dyn3) Move from thinking at the individual to thinking at the societal community and/or the other stakeholders	Everybody should just realize that we need to cooperate. We are not going to succeed if there are only a couple of people. (SF2) When I have thought about the future, I have always just seen myself. I have never thought about the people around me or what is happening around me. (SF10)
	(Dyn4) Think creatively for imagining new possibilities and concrete actions	Now I see more possibilities. Not just the one I had, this plan I was focused on to do that. I've always been so stuck on one plan, and never thought of going on a side-track, maybe something related. (SF10)
	(Dyn5) Balance the need of aspiring and desiring, and that of keeping feet on the ground	I know now that it is alright to dream big, these things are happening in real life, real days but yeah we still have a long way to go and I realized that I thought a lot about changes we needed to make in the world but not about how we make those changes, how we change all the things that are bad. (SF15)
	(Dyn6) Think in a multidisciplinary way, breaking down the barriers among disciplines	Humanistic and technological aspects were very intertwined ... ethics was interspersed with technological development. (SF19) It was also a brilliant example to see that in the world of jobs you need to develop transversal skills, you can no longer be too attached to the 'engineer', for example, and I be just an engineer. You need to be able to collaborate with various experts and be able to understand and help them. (SM22)

	(Dyn7) Move from thinking in terms of necessity to thinking in terms of multiple possibilities	Yes, we cannot actually know the future, but we can only say: "This is more likely to happen than in relation to". Another tool could be to know that there is not only one possibility, but different ones and we must take into account all of them in order to be ready and face the future. (SM23)

The graph in Figure 2.11 shows the distribution of the skills perceived over the students.

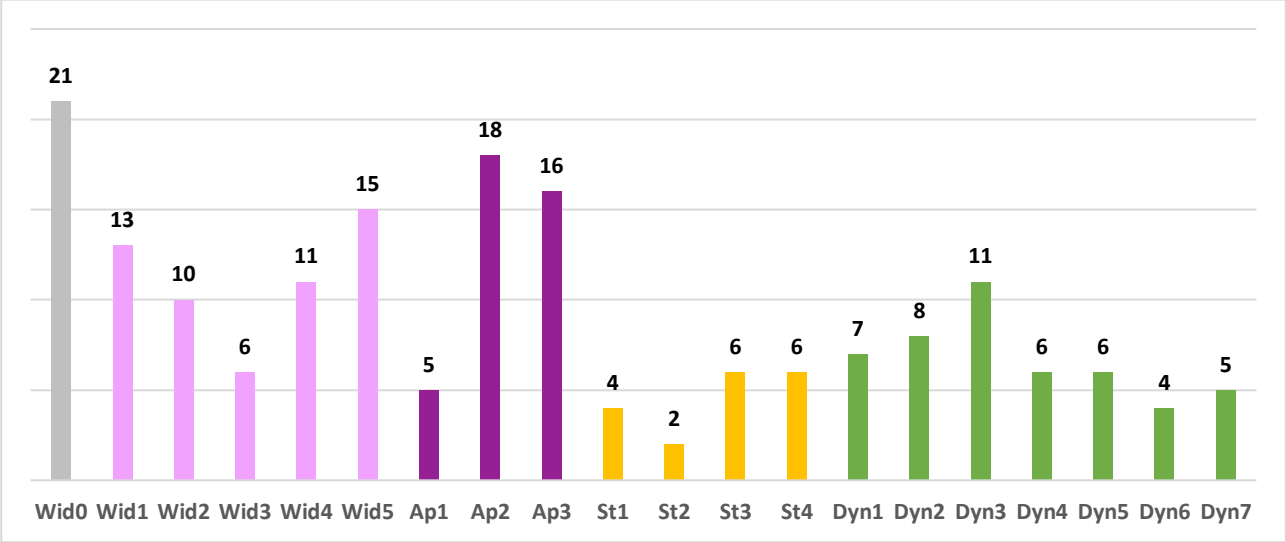

Figure 2.11. The total appearance of the skills perceived

The graph shows that all the categories are well represented and the data are significantly distributed. This can be read as a signal that the categories are able to capture general trends that the teachers and researchers perceived during the Summer School and no splitting or new aggregation among the categories are needed.

Within approaching, Ap1 (*The future became closer to students' imagination, i.e. from far and unimaginable, it became thinkable to them*) appears less frequently with respect to the other two type of approachings that are instead very well populated. This low occurrence looks highly reasonable, since it refers to something at middle-long term and it refers to the "imagination dimension" that is particularly difficult to develop in short time.

Another evidence is that the structural skills appear less frequently than the dynamical ones. This can be also due to the difficulty to describe them; the dynamical ones are easier to be described also without specific questions in the tools of data collection since they require a narrative style. Instead, the description of the structural skills can require a specialized language. On the basis of these remarks, the fact *per se* that many students show them is a very interesting and positive result.

Concerning the dynamical skills, we notice that Dyn 4-5, like Ap1, refer to a personal, private and imaginative dimension and the fact per se that they appear is an impressive result for a one-week course. The dynamical

skills that, instead, appear more frequently (Dyn 1, 2, 3) refer to dimensions that seem to belong to a public debate and, in this sense, it makes sense that the students are more sensible and more reactive on these aspects.

In order to have a detailed picture and see how these skills were distributed along the whole group, we built a graph (see Figure 2.12) that shows the distribution of Widening, Approaching and the skills organized per student.

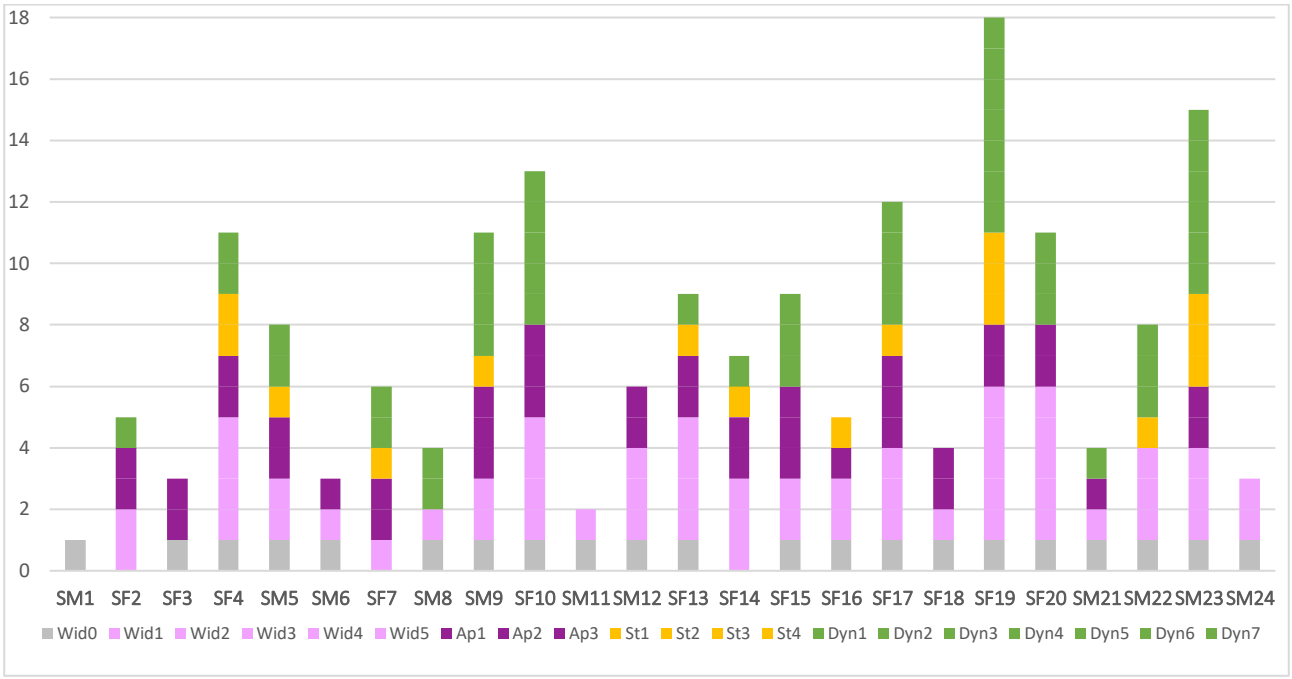

Figure 2.12. The distributions of the Widening, Approaching and skills per student

From this graph we can say that both Widening and Approaching are widespread over the students (by covering all three countries) and only one case does not show any Widening and Approaching (SM1).

From this graph we can also deduce that students' profiles can be identified and, particularly useful for the next step of the analysis, that "group profiles" can be identified. Indeed, the outline of groups' profiles from these data about students' perception is a crucial step for passing from skills perceived to skills in action.

The figures from 2.13 to 2.17 show the profiles of the groups of students that were set up for the final activities of the summer school aimed to develop a project, that is to design a "success story" where a problem in the future is solved and the group has to tell how the "success" was possible through a back-casting story. The 24 students of the summer school formed 5 groups, named according to the title of their success story.

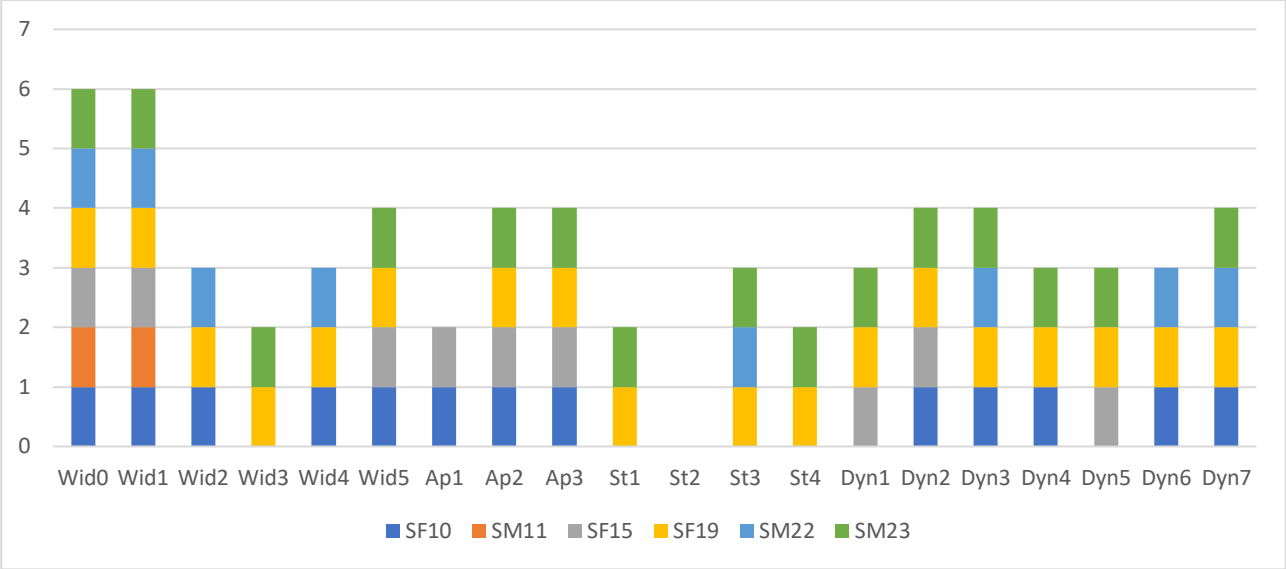

Figure 2.13. Profile of "Talk Show" group

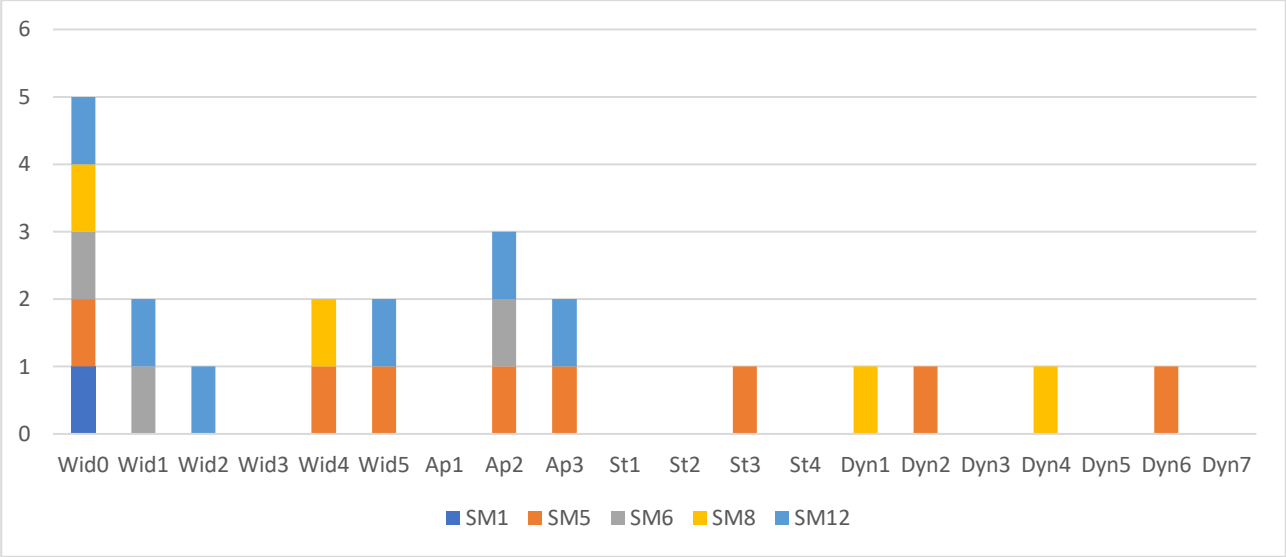

Figure 2.14. Profile of "Melting glaciers" group

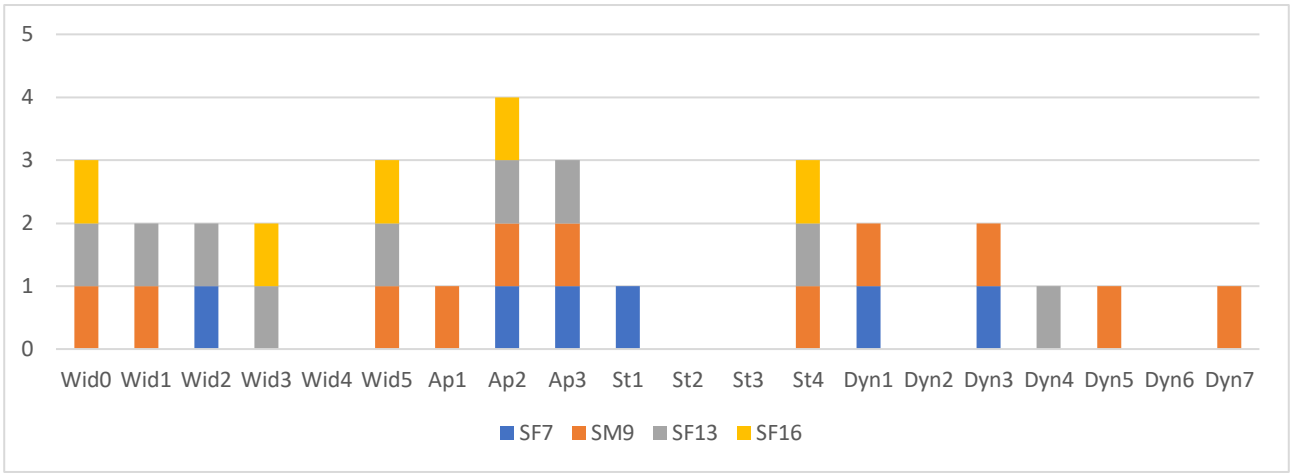

Figure 2.15. Profile of "Back in my day" group

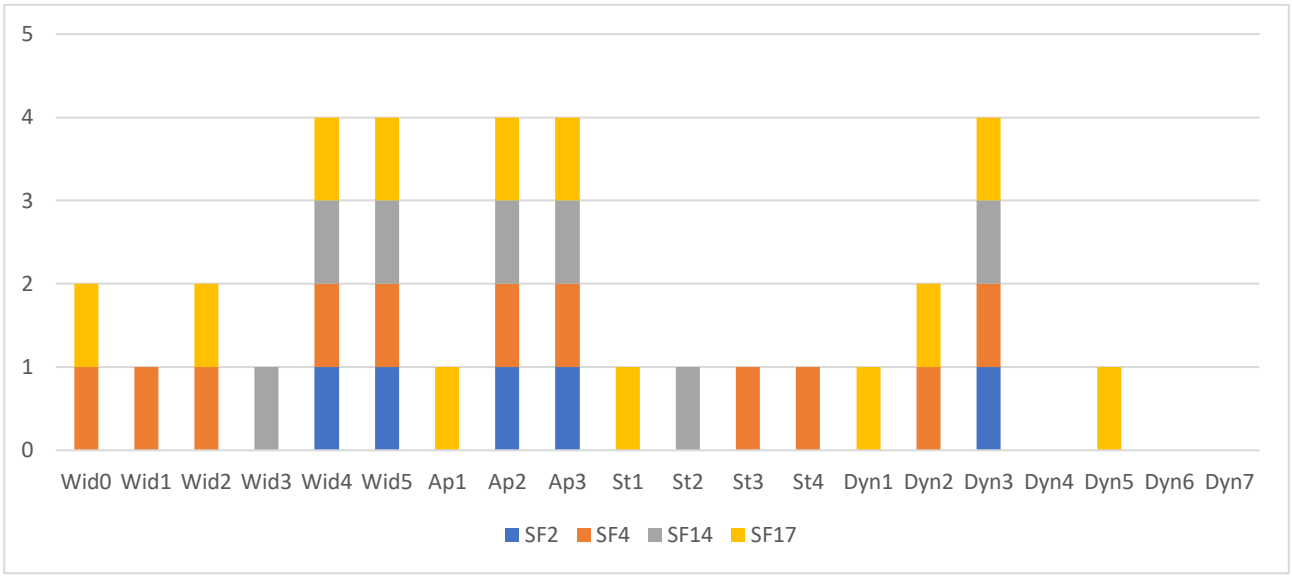

Figure 2.16. Profile of "Eco-friendly" group

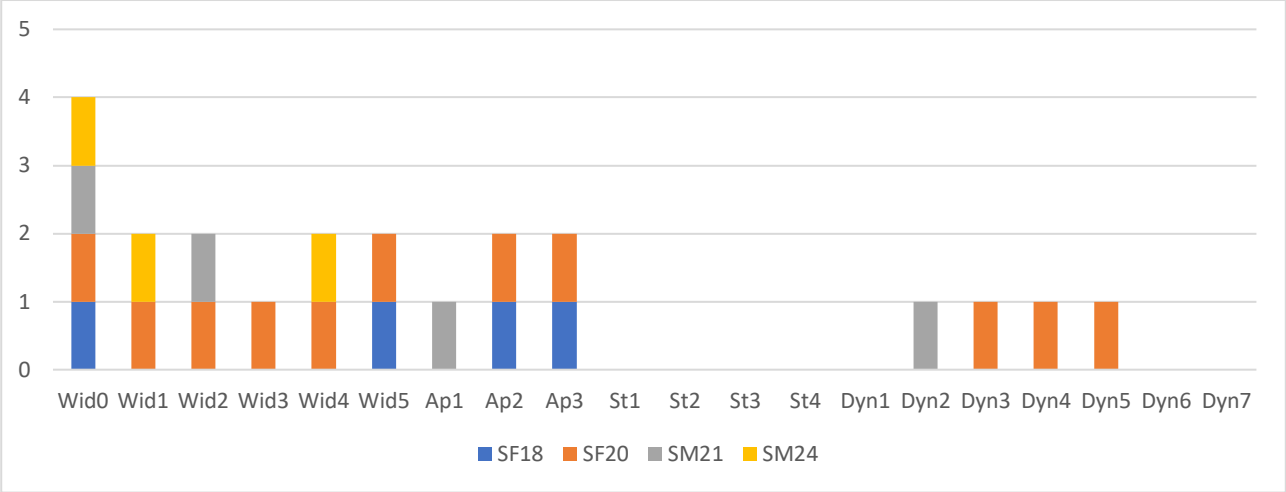

Figure 2.17. Profile of "Unhealthy cities" group

These profiles appear very different: in a rather evident way, groups of figures 2.13, 2.15, 2.16 shows a richer distribution of Widening, Approaching and perceived skills than the groups of figures 2.14 and 2.17.

Result #2 –The impact of the I SEE module on students' development of future-scaffolding skills

As already anticipated, in order to check the reliability of the skills perceived by the students, we decided to consider the videos of the final products and to sort out the skills that emerge directly from students' actions and discourses.

During the last phase of the summer school, the students were divided in five groups to produce their final output in the form they preferred: a video, a picture, or theatrical presentation. The groups were formed in a bottom-up way, according with students' desires, similarities of values, interest with respect a certain topic. The groups were mixed up in terms of gender and country balance, only one group was formed only by males.

We decided to analyse in depth the final outputs of two of the groups, "Talk show" and "Melting Glaciers", since their profiles appeared very different among them (figures 2.13, 2.14). Moreover, these two cases were selected because also the final videos, at a first glance, appeared rather different.

A first common consideration, emerging from the analysis is that some skills emerged from the structure of the work and some other from sentences pronounced by the "actor", even if in certain cases the markers can be traced in specific sentences said by one student, we retain that the interaction among the different characters, orchestrated by the direction, lets the skills emerge as an achievement of all the components of the group.

"Talk Show" group

The group formed by SF10, SM11, SF15, SF19, SM22, SM23 decided to structure their final presentation as an episode of a talk show: "Our history". During the show, set in 2030, five individuals were invited to talk

about their role in and their views about the so-called fifth revolution, the revolution of electric transports. The guests were an environmental geologist (SF10), the researcher that designed the technology at the basis of the realization of faster charging and longer lasting batteries for the vehicles (SF15), the politician that encouraged the revolution (SM22), the owner of an electric cars company (SM11) and a supporter of carbon fossil fuels (SM23). The video can be seen here.

In the followings, we illustrate in more details the students' presentation, highlighting the moments in which we recognize signs of change of future perception (Wid and Ap) and of future-scaffolding skills development (St and Dyn).

From the very beginning of the presentation we recognize Wid3 and Wid4 by the choice of involving in the discussion a wide range of stakeholders, both expert and non-expert (00:20). In the first part of the show, SF10 and SF15, the two scientific characters, explain to the audience the novelty of the technology behind the new functional electric vehicles with respect to old fuels: in particular, we recognize Wid0 when SF10 defines what fossil fuels are and why they are non-renewable sources of energy (03:55). Going beyond the disciplinary widening, the group shows a Wid1 when SM22, the politician, illustrates the timeline of the fifth revolution, echoing the idea of backcasting introduced by the futures studies (16:18). Also Wid5 can be traced in different moments of the students' presentation, in the different types of actions carried out by the different stakeholders (e.g. launch of the innovative fuels factory, start of pro-climate policies),

The approachings are well represented throughout the whole presentation. For example, SM22 says that at the beginning they "did not see what to do and where to go" (15:15) to address the issue, expressing that they felt the future far and difficult to imagine. But this perception changed when they "started to consider new opportunities and imagine multiple possibilities" (15:25) (Ap1) and began to think in terms of concrete actions, as the ones presented in the timeline overmentioned (Ap2).

For what concerns the systemic-structural future-scaffolding skills, we recognize St2 when SF19 (17:18) shows a map in which the group represented which they considered difficult, medium and easy topics related to the problem of energy supply (e.g., respectively: air transport, sustainable housing and private vehicle transport). The structural organization of the problem allowed to unpack a big and multifaceted issue (the energy supply) and to identify, among the parts, a problem (private transport) that was addressable for them.

Also the causal reasoning (St3) is strongly traceable in students' presentation. About this point, we have to say that the linearity of causal links prevails on more complex reasonings. The entire story told during the show is a story of success: from the research on batteries to the investment by the government, from the incentives for buying new electric cars to the ban on circulation for fossil-powered vehicles. Even the promotional video produced by the students and showed at the beginning of the presentation contains very linear and apparently naïve statements like "electric cars were being developed and finally people started to use them, and the conditions of the earth improved" (01:44). We think that these claims can be justified by the context in which they are told: a television show with the goal of informing and convincing the audience about the social, economic and environmental value of the fifth revolution. Indeed, linear statements are typical of propaganda: they have to be, at the same time, persuasive and easy to understand, hence they often emphasize the message they want to communicate, *via* a sharp selection of the contents and of the

events. However, during the show there are some moments in which the linearity of this story of success is softened. We trace signs of this in the recurrence, especially in SF10 and SF15's talks, of the verb "contribute", when they explain the role of the new batteries for improving the conditions of the earth (e.g. SF10 at 06:26).

The non-linear dynamical skills are present during the entire presentation. The same "idea of longer lasting and faster charging batteries for electric cars", expressed by SF15 (09:48), is a manifestation of the development of Dyn4, as a creative concrete action to influence the future. Also the concept of dream and utopia is well-balanced by the group with a concreteness that shows the need of keeping feet on the ground (Dyn5): this is expressed by SF19 when she illustrates the problem of air transport, explaining that the solution would consist in a "sustainable way of travelling, because we cannot stop travelling" (17:30).

But the core of the presentation is the discussion between SM23, the pro-fossil fuels protester, and SM22, the politician who mainly supported the fifth revolution. SM23 is convinced that the past with its "old good days" (12:44) was better than the present thanks to fossil fuels. His arguments, centred on his present interests and needs, are summarized in the following sentence: "when we used fossil fuels we were happier, vehicles were faster so we used to get home earlier, whereas now you have to take your electric car and it takes a lot to go, because you are very slow. I could run on the street and make races with other people, nowadays you can't" (11:05). The ironic spirit of SM23's talk becomes more evident in the second part of his intervention when, sneering, he recalls "the smell of fossil fuels… when you woke up in the morning, you opened the window and it was perfect. Also the noise of engines was music for my ears, these noiseless vehicles are just stupid" (12:22). With his quasi-comic tone, SM23 seems to make fun of simplistic analyses like his own: trapped in the present without any view on the future, in the local small world in which one lives and in the contingent needs or pleasures of individuals.

Here comes SM22's talk that starts with a completely different tone telling the story of the revolution. This story began under uncertainty, since they "did not see what to do and where to go" (15:15) but, after having "considered new opportunities and imagined multiple possibilities" (15:25), they started to act. In his intervention, SM22 not only illustrates the timeline of the fifth revolution but also tells his personal story: "initially I was a small politician, but I felt a great responsibility toward these people and their wish for a greener world and a greener future for our children" (21:18).

From this debate between SM23 and SM22, that we have here summarized, we recognize in a peculiar way the emergence of other three dynamical skills. In particular, about Dyn1, Dyn2 and Dyn3 that regard a transition between two ways of thinking, SM23 represents the starting point – thinking locally, at the present moment and at the individual contingencies and needs – while SM22 personifies the realization of the skills – thinking globally, at the future and at the societal community.

"Melting Glaciers" group

The presentation carried out by the group formed by SM1, SM5, SM6, SM8, SM12 was centred around the problem of the melting glaciers and the students' idea for contrasting it, i.e. to cover all the glacial surfaces on Earth with aluminium foils. One student, SM1, conducted most part of the presentation and another one,

SM12, participated in few moments; the other three students were silent during the presentation. The video can be seen here.

In the followings, we illustrate in more details the students' presentation, highlighting the moments in which we recognize signs of change of future perception (Wid and Ap) and of future-scaffolding skills development (St and Dyn). Generally, the presentation was weak on both the aspect: to show this, we show and argue how not only some perceptions did not change and some skills were not developed, but also how even *opposite* attitudes can be traced.

The only widening displayed in the presentation is the disciplinary Wid0, when SM1 talks about the physics behind the melting phenomenon, including the albedo effect taught during the summer school. There is no sign of any other widenings: there is no reference to any method or concept of the futures studies (no Wid1) and the story is told only from a scientific-engineering perspective, without any contradictory opinion and without introducing diverse ways of tackling with the issue (no Wid2). Strictly related to this point, in the presentation the concept of stakeholder, both experts and non-experts, is completely absent (no Wid3/4): even after an explicit question, the only professional role that SM1 foresees for all the members of the team is the "engineer" (17:42) working for a "company".

We cannot find any marker for approaching in the presentation. We think that this is due to the central idea elaborated by the group: it is so unfeasible and science fiction that it seems not to activate any change in the perception of the future that remains far from students' imagination, present reality and career.

The structural skills are mainly expressed through the causal map drawn by the group to highlight the "things that contribute to the sea level rising" (00:44). Even if the students identify some of the factors leading to this phenomenon, they do not mention nor represent in the map the positive feedback loop at the basis of the melting of glaciers: the causality is linear and there is not any sign of taking into account more complex reasonings.

But the most critical point of the presentation is represented by the absence of dynamical skills. On the opposite, there is a sort of resistance displayed by the students at thinking globally (no Dyn1). Their idea of covering the glacial areas with aluminium foil was elaborated with a very local objective: this is evident when SM1 explains that the costs of such an intervention should be covered by "a coalition of Antarctic countries or of areas where there are glaciers on" (11:50), as if the problem of melting glaciers affected the areas with glaciers – that is also unreasonable since where there are glaciers there is not the sea – and was not a global problem.

The comparison of the two cases shows an interesting and substantial relation between the perceived skills and the skills really put in action. Such a correspondence reveals the efficiency of the markers we pointed out to capture a phenomenon that really occurred: the I SEE module can have important impact on students' perception of the future and on the development of future-scaffolding skills. Now that we are able to identify the learning outcomes that we can produce, it will be also easier to improve the modules and address the problematic cases that we recognised in this first implementation that was also particularly complicated because of the international context.

Result #3 – Cultural differences (as an emergent property)

The cultural issue appeared to be a constant reference. They revealed that the meeting with different cultures gave the students something beyond conceptual knowledge, that is, an awareness of others' lifestyles, approaches, ways of reasoning, environmental cultures, etc. but dealing with the same problems:

> "*It was very interesting because we have seen different approaches from countries with different climate, structures and territories in dealing with the same problems that affect all of us, because we are all inhabitants of the same Earth. This experience pleased me a lot because there is always one more point to consider; there is another way to get the same solution. This fact that problems can be addressed by different points of view, more or less favourable depending on where you live, where you are working and with the means you have. I've absolutely appreciated this opportunity"* (ITA).

What emerged with a strong emphasis from all the three different countries is the great opportunity they had to share values and desires to act together for changing the world internationally. This agreement was reached not suddenly and not easily because at the beginning, several problems were encountered. Table 2.9 reports the typologies of problems they had to face.

Table 2.9. Initial difficulties encountered by the students

The **problem of language**, some Italian students highlight their difficulties in speaking in English and some students from the other countries highlight the initial difficulties in understanding the Italians.	*I think the main difficulty was the language, because talking about science in English, which is something I'm not used, at beginning perhaps represented a step to overcome. (ITA)* *The Italians were more open but had a harder time with English. (ICE)* *I didn't understand the English of the Italians (FIN)*
The problem of having a very **different cultural background** in terms of experience, ways of expressing, behave, society around, etc. and of finding a common "trading zone"[1] (Peter Galison)	*I learned a lot of patience and organization this week, how these different countries have different ideas around the topics we worked with this week. The different cultures have different ideas. (ICE)* *We needed to exercise patience in working with some people. I learned about planning better what I'm going to do, to think carefully what I'm going to say. (ICE)* *Maybe it was difficult to agree the various ideas among different nationalities and to do group work because this was not always easy accomplishment, because maybe it depended a lot on the different interest. That is, perhaps create a group where ... there were many conflicting ideas generated after relationship difficulties. (ITA)*

[1] The metaphor of a trading zone is being applied to collaborations in science and technology. Peter Galison produced the "trading zone" metaphor in order to explain how physicists from different paradigms went about collaborating with each other and with engineers to develop particle detectors and radar.
The basis of the metaphor is anthropological studies of how different cultures are able to exchange goods, despite differences in language and culture.

Hence, there were difficulties in overcoming some initial barriers (language, behave, ways of expressing themselves, structural diversities, …) but after having overcome the initial barriers **the cultural differences became fruitful and a chance to learn**:

> *I felt like the Italians were really willing, and as soon as you could get over the language barrier everything opened up really well. (ICE)*
>
> *It was different working in groups here than at home. Communication was harder. Everything took longer. We were not as much in agreement either.*
>
> *I learned a lot of patience and organization this week, how these different countries have different ideas around the topics we worked with this week. The different cultures have different ideas.*
>
> *It was though easier because everyone here wanted to be here. Everyone was more willing to work than at home.*
>
> *I expected everyone to have different opinions and cultures, and I didn't have to learn to be patient with the differences. I didn't learn from that, but I learned a lot from the differences. (ICE)*
>
> *Maybe it was difficult to agree the various ideas among different nationalities and to do group work because this was not always easy accomplishment, because maybe it depended a lot on the different interest. That is, perhaps create a group where ... there were many conflicting ideas generated after relationship difficulties. But when the little we were put together for interest in working on a problem to which we hold, it was much easier. (ITA)*

The multi-cultural relation was positive and fruitful from many different aspects, as it was showed in table 2.10.

Table 2.10. Positive aspects about the multi-cultural relation among the students.

The challenge and the satisfaction of finding an agreement	*When we began to make our project which we then presented this morning, that we put 45 minutes at the beginning because we could not find an agreement [...] there was a moment when we could not do well, and that was a difficulty. Then we succeeded into find an agreement. However, we were seven, we were in a group, there were seven brains that thought and had ideas, that need to get to a unique solution and this is not easy, particularly when there are imagination and creativity in the game. (ITA)*
The surprise and the satisfaction of sharing the same problems	*It was nice to hear that there are also other people who have similar interests and they had new and different ideas [of solutions to the problems]. (FIN)* *Many new keys to interpret what I want to do, also thanks to the relationship with other students from other countries. (ITA)*
The exchange of values with other young from other	*This, yes, and the comparison with the other boys of the other nationality, for example I was in the room with two girls Finnish and*

countries let them able to **create deep relationship, based on important things** and also to argue with respect difficult arguments, even though they know each other only from few days.	*Klara - which was the one from Iceland - was often with us … And ...and ..., so enjoyed talking maybe things ... on the fact that in any case here we have addressed the problem or at least very difficult issues, we were talking about maybe just as complicated and difficult things that go well maybe just had nothing to do with climate change, though it seemed normal to talk about complicated things that even with people we know for a long time we have never talked before and we talked about it quietly with people we know precisely four days. I say, I know them only from four days, and instead I think to know them from more time and more in depth in this way. (ITA)*
Encountering different cultures and perspectives make you able to enlarge your horizons and open new perspectives	*We have been able to exchange ideas and also very nice initiatives, because we see a lot of difference in mentality. I could see how, compared to our mentality, Icelandic is much more open on the most varied issues, which can be environmental issues, social and relational issues, being together, accepting diversity and also the diversity of ideas. For example, my roommate was strongly feminist and did not feel uncomfortable about this, indeed it was supported by friends who had the same ideas, but even those who do not have the same ideas, however, respect the diversity of others. But here, maybe if you take a position in society you risk being derided because they think it's just a fashion and instead maybe one does it because it really believes in what it does. (ITA)* *We have met different cultures, people who come from very distant countries, this is a great enlargement of our horizons. We met people with opinions, completely different opinions and this questioned me, made me discover the reasoning I had never done and made me humbly stand before the opinions of others. These meetings discuss their ideas and in this way evolve. (ITA)*

We can infer that, more than we expected, the cultural issue has been relevant during the summer school and, despite the initial difficulties, the variety of the context represents an important added value.

2.3 Final remarks

As a final remark, this study allowed us to refine previous categories and to capture the macro-phenomenon we observe when students cope with future-oriented activities. We also realised that the positive attitudes towards the future matured by the students are linked to the feeling of having developed important systemic-structural and dynamical skills. In this sense, the development of future-scaffolding skills seems to impact the emotional dimension. Now that we have pointed out these skills, the future refinement of the modules will be explicitly oriented to develop them so as to proceed, in the next rounds of data collection and analysis, to refine their description and to investigate in more detail their emotional impact.

Chapter 3 – Other studies and theses

Parallel to the work on I SEE Case studies, the Finnish partners carried out separate analyses, and data from the Finnish I SEE module implementations were analysed in order to strengthen the interpretations and results from the official Case study analysis. Moreover, there are a notable number of theses on I SEE related themes supervised by I SEE researchers.

3.1 Other studies on I SEE

During the three Finnish I SEE module implementations, an extensive amount of data were collected in the form of written essays, questionnaires and individual interviews. The data collection tools were similar to the ones used in the Summer School but slightly altered and adapted to the new context.

The findings from the parallel analyses show the potential of I SEE modules in general – and not just the Climate Change module – to enhance students' capacity to aspire to and to imagine their future through inclusive activities in science education.

3.1.1 Ways students use to talk about the future before I SEE courses

At the beginning of each Finnish I SEE course, students were asked to write a pre-essay on a summer day in 2035 or 2040 and answer questions regarding their future. Essays (N = 55) were analysed using discourse analysis in order to identify the different ways young people use in speaking about the future. Future Studies' categorisation of the ways to see the future (*i.e.* Voros, 2003) was used as a starting point for the analysis, and ways of speaking about the future were divided into three categories: 1. the future as a linear extension of the present; 2. plurality of futures (scenarios, narratives); and 3. preferable futures according to values, visions and choices. The categories and some exemplar quotations from the data are presented in Table 3.1.

Table 3.1 Categories from the analysis of Finnish pre-essays.

1. Linear extension of the present	
STABILITY: The stability of human nature (slowness of evolution). Things that are meaningful to a student will be rooted to the future.	*Despite all these developments, the life of an individual has not changed in terms of its basic characteristics, at least not in my case. Sure, everyday objects now include more technology and have new features – which the wealthy already consider essential – and friendships are global and not limited by physical distances, but people still work, eat and sleep, enjoy each other's company and gaze out to the sea – whether it is through the screen or a real window. (Viivi)*
EXTRAPOLATION: A plausible alternative based on realism, rationality and causation. The future is seen as a continuation of the present. Causal relationships are formed by linear comparison between the present and described future. The speech demonstrates a strong internalization of cultural conventions. Questioning those conventions is not seen to be possible, and they are rather seen as predictors.	*Thanks to technological advances, everyday devices such as phones, cameras, and other screens have become faster and more accurate. (Kerttu)*

2. Plurality of futures	
The future is described as an alternative and often as one out of a variety of scenarios. These alternative scenarios challenge assumptions. The speech proposes novel solutions for replacing existing activities. Those solutions are not (directly) linked to linear continuities or causal relationships. This way of speaking represents most clearly the ability to think creatively.	
SCENARIOS: The speech often describes the environment and organization of its activities. Alternativity, uncertainty, and opportunity are described in neutral terms, such as *I think, I believe, possibly* (which do not imply that the author speaks about their own value-based desires).	*In the Helsinki Metropolitan Area, traffic is already based on automated vehicles; trams and buses as well as private cars follow the algorithms that are programmed into them. Traffic is monitored from dedicated centres, whose employees can take control of the vehicles in the event of a breakdown or dangerous situation. The potential problems caused by self-driving vehicles have been evaluated as being worth the benefits. (Viivi)*
NARRATIVE SCENARIOS: In this type of speaking, "I" is strongly present. Often, the author makes up a story about their future day, describing what they do, what kind of world they live in, how things are organised in the future, etc. The story often covers the whole essay. Although the "I" is at the heart of the story, sometimes the author creates a frame narrative that describes the surrounding circumstances in more detail. Within the stories, scenarios and pictures of the future world are produced.	*It is year 2040. The sun is shining, and it's raining. Sounds like a perfect Finnish summer day. I'm out spending some quality time with my friends, when a message pops up in the upper right corner of my smart contact lenses: I have received a text message from my boss, telling me to get to the office immediately. I say goodbye to my friends as the electric car I ordered with my smart contact lenses stops by the sidewalk to pick me up. Private cars have become rare, since everyone uses shared, self-driving electric cars to get around. While the car drives me to the office, I use my smartphone to check the situation. Apparently, either Russian or Chinese hackers have again launched a denial-of-service attack on our company's servers, and something needs to be done about it. Since I am one of our company's chief engineers, I have been alerted to the scene even though I am on holiday. (Pasi)*
3. Preferable futures according to values, visions and choices	
Talk involving values often contains future solutions based on feelings and values. These topics are often value-laden (ecology, ethics, etc.). Typical expressions include: *I wish, I hope, and I dream of.* The future is constructed through one's own hopes, desires and dreams. • Often, the starting point is unlimited possibilities (sometimes commented on by linear "realistic" statements against one's own dreams or by constructing an alternative scenario). • When used to construct one's future of dreams and aspirations, there is often lot of conditional use. This also reflects the author's uncertainty about their wishes. "I-speech" is often put into this category because authors often express their own opinions and values through themselves. Opinions and values have a powerful influence on images of the future. In some cases, the speech produced through a person gives rise to interpretative problems: sometimes it relates to values and sometimes to other categories.	
In 2040, I hope to live in a warm country with my family and to work in my dream profession. The city where I might be living is near the beach. My house probably utilizes solar panels. We own an electric car, but we also use our bikes quite often. In my life, I will travel a lot with my family and explore the different habitats on Earth. *I hope I will still be a vegetarian, like I have been for the past year already. I strive to live ecologically, because even though I am young, I am aware all the causes and consequences of climate change. I do not want to be one of those people who do care about giving a better life and a more sustainable Earth to the next generation. (Juulia)* *In the future of my dreams, we would have solved the world's problems, such as climate change and poverty, and people would be more equal than now. These problems are unlikely to be resolved by 2040, but technology can help, in particular when it comes to combating climate change. The problems I and the community face could be as minor as possible, such as a small morning rush or a queue at the most popular café before work starts. (Aada)*	

From the essays of Finnish students rose largely the same themes as in the study introduced in Chapter 2.2.2. The preliminary analysis shows that the most common way to talk about the future is reflecting on one's own desires, wishes and dreams. Creating linear sequences and producing multiple scenarios are also common ways of speaking. While the analysis is still in progress, cautious anticipation of the results reveals the ability to think of multiple futures linked to technological interests. In the data, it is also possible to identify linear thinking, strongly based on continuity and causation, leading to prospects, in which technology is perceived as a threat.

3.1.2 Changes in students' thinking during the first Quantum Computing course

The interview data from the first Quantum Computing module implementation were transcribed and analysed soon after the implementation. The preliminary analysis did not aim at defining the future-scaffolding skills but focused on students' future perceptions and how those were impacted during the module implementation. The analysis fleshes out the ways students speak about futures and agency, quantum computers, STEM disciplines and careers. The findings illustrate the changes happened in students' thinking during the course and support the interpretations made from the Summer School data. Some exemplar quotations from the data are presented in Table 3.2.

Table 3.2 Quotes about futures and agency from the first Quantum Computing module implementation data.

1. Views of the Future - Fears and Concerns	
Optimistic view of the future: diminishing of fears and sense of threat; belief in that negative developments can be stopped	*[My way of thinking about the future] has become more positive [...] Maybe it, it creates more hope, just like I said before that when there are people who think the same way as you do, that you don't start feeling like "there's no point in this", like "why bother doing this", but it gives you motivation to try your best so that bad things wouldn't happen in the future. (Teo)*
View of the future consists of both hopefulness and threats	*Well, the biggest ones [worries and fears] have changed a bit in the sense that they have become smaller. Like, after all, when you look at the development of the world, it's been a way up all the time .. Although of course climate change scares me but .. anyhow, I now feel that the future is looking bright. (Hanna)*
Pessimistic view of the future: fears and threats remained / view of the future tied to negative connotations	*–a kind of economic inequality [is a future threat], because it has grown so much, if you think like somewhere in America, like it's steadily growing, and maybe here as well (Maija)*
The future is unpredictable and uncertain	*I also see that .. how technology develops, that there's no way of knowing, or it's hard to say. That in what way .. you can't sort of fathom it (Liisa)*
2. Futures Thinking Skills	
Creative thinking, recognizing and questioning assumptions	*Well, maybe [my own way of thinking about the future changed] into being more organized, but on the other hand .. also .. I've been starting to question some assumptions. [...] [it feels] maybe a bit more positive .. if you think about solutions, for example. (Patrik)*
Scenario thinking, multiple futures	*–in scenario thinking you had to be open to all possibilities in a way, which was kind of the same as when we looked at the [quantum logic] gates, you had to be open to even the really illogical options. So, they both kind of taught .. helped develop a kind of creative thinking. (Liisa)*
Backcasting	*It [my way of thinking about the future] has changed, mainly through backcasting. (Inka)*

Systems thinking	*I think the concept of a leverage point is a really good way to think about, that, I don't know. I just hadn't thought about it before [...] But I mean leverage points more in the sense of modelling an entire system and all its interacting parts, and looking for the part that would have the desired effect (Joel)*
Unspecified broadening of horizons / ways of thinking about the future	*–I felt like every time I .. if I thought about the future or tried to predict it, it was like really haphazard but now it feels much more certain [...] that it, it doesn't matter if what I predicted actually happens but just the fact that I have thought about it helps me prepare for .. whatever comes. So, like, I feel like that way I learned a new way of thinking, like a new process. (Liisa)*
Ease and meaningfulness of thinking about the future	*Well, maybe it [thinking about the future] is easier now .. with the help of those techniques [backcasting, scenario thinking] (Hanna)*
Only slight changes in futures thinking or change is difficult to put into words	*Definitely. It [my way of thinking about the future] has definitely become broader and .. I can't say exactly, what has changed, but .. it has changed for the better, of course (Olli)*
No changes in futures thinking	*I don't think [there was any change in my futures thinking] (Aatu)*
3. Personal Futures	
Using futures thinking skills in building personal future	*Well, for example if you can't decide on what to choose, and you think about what would happen if you chose this instead of that, and you used some imagination. Then .. that could be helpful, and you could also use it [futures thinking skills] for example in making good choices, that could be helpful. (Samuel)*
Ability to influence one's own future seen as nearly unlimited	*I think my future .. is in my own hands for the most part. It is possible that something happens that I can't prevent or change. And that includes all these political matters that might change, and they are completely out of my hands but .. I do believe that my future is relatively strongly up to me and the effort I put into it. (Tatu)*
Education/studying is central in influencing one's own future	*–I've always felt very strongly about [...] the importance of studying and getting, finishing a degree. So, I feel that that's in a way the first step [in influencing my future]? Like, it's a good foundation. (Liisa)*
Determination, perseverance, diligence, the right attitude is central in influencing one's own future	*Well, [I can influence my future] a lot. Not nearly in everything, of course. And, well, actually there's probably a lot that I can't influence, but I'd say I can influence it very much, and .. you can use your attitude to make a difference too. (Moona)*
It's possible to influence one's future, but it's not necessarily clear how it can be done.	*At least my own future [is something I can influence], yeah. [...] through all the decisions I make .. Some are more, and some are less but .. life can really be difficult to plan, but they do say that what happens is not as meaningful as how you react to what happens. And .. if think that's a very true saying. (Joel)*
Future view seems vague/incomplete or the future hasn't been given much thought	*Yeah, I feel that way [that I can influence my future] .. Like right now I haven't planned .. planned like .. anything regarding my future, apart from my studies. But .. until now I haven't felt like I need to either. (Janne)*
Uncertainty, limited possibilities, challenges	*–but somehow I felt as if I don't know enough [about the differences between study options], because I have friends at Aalto University but not at the University of Technology, and so it feels a bit uncertain, what I will end up doing (Silja)*

4. Influencing Other People and the Future of the World/ Society	
Influencing the future is possible through work and personal successes attained through work	*–hopefully I will be in a profession that develops the world, you know, that tries to come up with new inventions and develop the society. So, I hope my job is somehow like related to that. So, if I get that kind of a job, I can automatically have an influence [...] so if I just do the work that aims at change and development (Elise)*
Belief in having the ability to create an innovation that will have an impact on the world	*Of course [I want to influence the society]. And, umm- .. I'd like to solve at least one problem or make an invention in the future .. I haven't decided what, but something good. I intend to solve something in the society [...] to help or improve people's quality of living (Olli)*
Influencing outside of work through actions, choices, expressing opinions	*I do like .. I got this feeling in our project that I think the members of our group could really have an impact on this matter in some way, if through nothing else, then .. in our project we talked quite a bit about getting .. the general opinion of people to change, that at least can be influenced through supporting the sort of opinions that you agree on and .. voicing your own opinions. (Janne)*
Influencing society through social roles - positivity, resolving conflicts	*–I'd rather just make sure that everyone is feeling OK .. be it working out disagreements or just being there to listen to others (Heikki)*
Influencing through networks and cooperation	*I hope that we could somehow openly have different cultures and bring them together and just have as many different people as possible, try to learn something new from everyone and just cooperate with as many as possible (Maija)*
Possibilities are very limited, difficult to imagine or not clearly defined	*Umm, on a societal level I can't [influence] very much, but very much so in single cases and in a smaller circle. You can influence individual people quite a lot, how they behave and so on, and then if you manage to influence many enough individually, it will create some kind of a change. (Teo)*

3.1.3 Future-scaffolding skills acquired during the second Quantum Computing course

The interview data from the second Finnish Quantum Computing module implementation were transcribed and preliminarily analysed during summer 2019. The analysis was implemented using the Future Scaffolding skills categories developed earlier in the I SEE -project (see Chapter 2.3.3). Transcribed interviews were coded using the known markers (see Table 2.7).

The results of the analysis suggest that operationalising the categories as an analysis tool is feasible. As can be seen in Figure 3.1, all the categories are well represented in the data. The results show signs of widening in the futures thinking skills and scenario thinking. Most of the students described changes in realizing the multiple possibilities in terms of possible future scenarios and the amount of knowledge in terms of future-oriented scientific issues and Future Studies (see Figure 3.2). Differences to results from the analysis on the Summer School data can be explained with the different subject matter and a slightly different interview protocol. At this point, the analysis is only preliminary and needs a more in-depth study to have results comparable with other analyses.

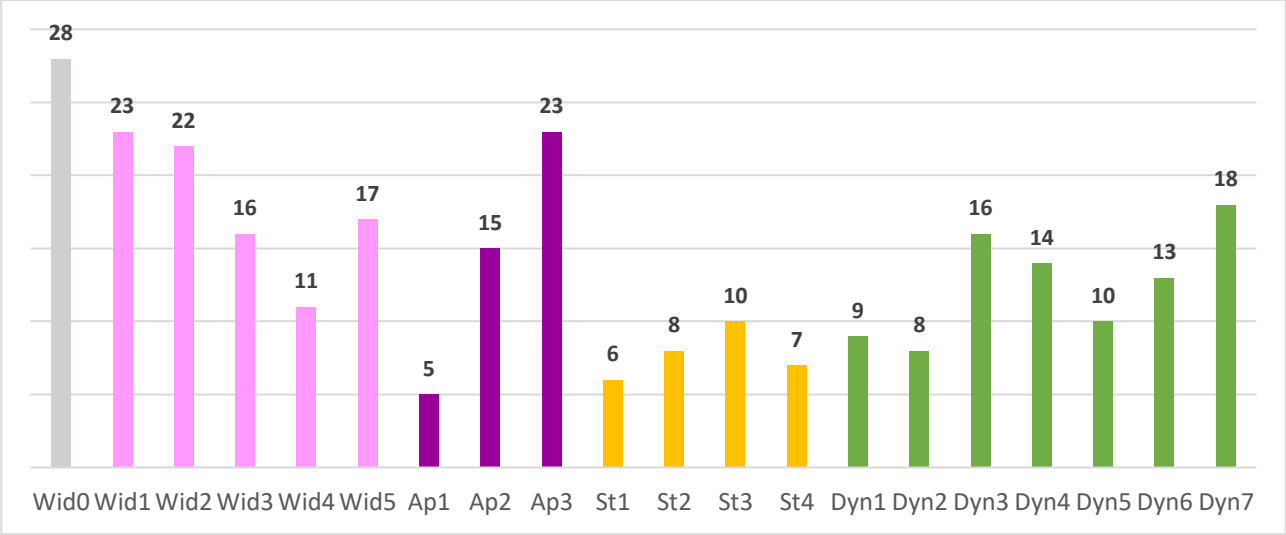

Figure 3.1. The total appearance of the skills perceived.

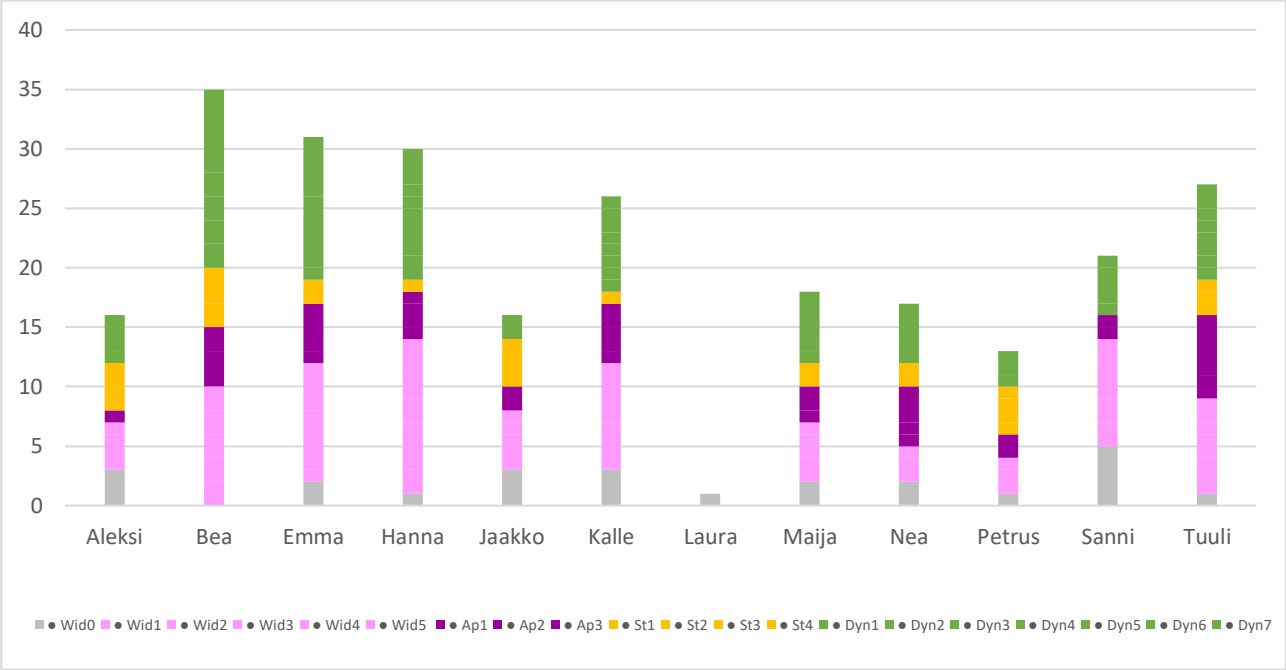

Figure 3.2. The distributions of the skills perceived by the student

3.2 Theses on I SEE

In addition to the analysis described above, four student theses on the I SEE data have been completed at the University of Bologna and three at the University of Helsinki.

3.2.1 Students' theses on I SEE from the University of Bologna

Barelli, E. (2017). Science of complex systems and future-scaffolding skills: a pilot study with secondary school students. Master thesis in Physics, Alma Mater Studiorum – University of Bologna. Advisor: Prof. O. Levrini. Co-advisors: Dr. G. Tasquier, Dr. L. Branchetti. Available at https://iseeproject.eu/wp-content/uploads/2017/04/EB_Tesi.pdf

Rigotti, L. (2018). L'intelligenza artificiale come contesto per un approccio STEM alla didattica. Bachelor thesis in Physics, Alma Mater Studiorum – University of Bologna. Advisor: Prof. O. Levrini. Co-advisor: E. Barelli. Available at https://iseeproject.eu/wp-content/uploads/2017/04/Tesi_Rigotti.pdf

Satanassi, S. (2019). Quantum computers for high school: design of activities for an I SEE teaching module. Master thesis in Physics, Alma Mater Studiorum – University of Bologna. Advisor: Prof. O. Levrini. Co-advisor: G. Ravaioli. Available at https://iseeproject.eu/wp-content/uploads/2017/04/Quantum-computers-for-high-school-_-SS.pdf

Spada, R. (2019). The Second Quantum Revolution: Designing a Teaching-Learning Activity on the Quantum Manifesto to Futurize Science Education. Bachelor thesis in Physics, Alma Mater Studiorum – University of Bologna. Advisor: Prof. O. Levrini. Co-Advisor: S. Satanassi. Available at https://iseeproject.eu/wp-content/uploads/2017/04/SpadaRoberta-thesis-onlinepub.pdf

3.2.2 Students' theses on I SEE from the University of Helsinki

Master's thesis on how does the I SEE Climate change module, and its action competence approach in particular, support students with learning disabilities (theses in English):

Jokinen, I. (2018). Learning disabilities and Action competence approach - an analysis of a learning module on climate change. Master's thesis. University of Helsinki, Faculty of Science, Department of Physics. Available at http://urn.fi/URN:NBN:fi-fe201801151769 .

Pre-service science teachers' seminar theses, analyzing the summer school data from the viewpoint of climate education (theses in Finnish):

Upper secondary school students' views on their social and political agency in the future:

Binios, A., & Valpas, K. (2018). Ilmastonmuutos – Nuoret tulevaisuuden toimijoina [Climate change – the young as agents of future]. Seminar study. University of Helsinki, Faculty of Educational sciences, Department of Education.

A case study on I SEE summer school participants' emotions and sense of hope about climate change:

Kulmala, K., & Penttinen, A. (2018). Lukiolaisten tunteet ja toivon näkymät ilmastonmuutoksen suhteen – tapaustutkimus [Upper secondary school students' emotions and sense of hope about climate change – A case study]. Seminar study. University of Helsinki, Faculty of Educational sciences, Department of Education.

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Abrahamson, D., & Wilensky U. (2005b). The Stratified Learning Zone: Examination of the Pros and Woes of Collaborative-Learning Design in Demographically-Diverse Mathematics Classrooms. In D. Y. White (Chair) & E. H. Gutstein (Discussant), *Equity and diversity studies in mathematics learning and instruction*. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada, April 11–15, 2005.

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