Fostering students' systems thinking through futures education

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Abstract

In an era of worsening environmental crises, students may not perceive themselves as able to impact and change the inevitably upcoming futures. Accordingly, a common goal of educational systems has been to develop students' agency beliefs and sensemaking in a complex world. Simultaneously, students are facing unprecedented levels of future anxiety, and educational institutions undervalue the importance of futures thinking. To take on a constructive approach on futures thinking, we examine how students' systems thinking skills develop during a futures education course in which they write their own visions of a hopeful future. By looking at the thematic spheres of society, nature, and technology, we analyse how students develop systemic understandings of the complex system that is the context of the study: the city of the future. The study examines how students' written future visions develop throughout the course, and how those changes indicate development in systems thinking. The results show that the futures education course allowed students to improve their understandings of the interconnectedness of the topics they raised, fostering more complete and active understandings of the futures, here shown through the multidimensional development of systems thinking. Students developed a deeper understanding of the interrelationships of society, nature, and technology, and advanced understandings of the pathways to change and the actions needed to achieve their futures.

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1.   Introduction

In a rapidly changing world, thinking about the future is increasingly important. Anticipation, forecasting, and scenario building, however, are challenged by uncertainty and complexity: from meteorological to political or social futures, the evolution of complex systems can be predicted only to a limited extent. In an era of environmental crisis, longer future predictions are often problematic to the point of pessimism (United Nations, 2023). Although such future predictions are highly researched and calculated scenarios, their intentions in evoking awareness and actions can backfire due to overwhelming sensations of helplessness and impossibility (Hickman et al., 2021). Moving between levels of global challenges and individual actions can be difficult as simple causalities are governed by systemic ones.

Addressing the need to help students orient towards uncertain and complex futures, the field of futures education aims to bring futures thinking into classrooms today (see e.g. Page, 1996). To build these capacities, futures education, as discussed by Hicks (2003), entails a conceptual framework of education about the future, focusing on the core skills of visioning, thinking, and systemizing. Futures education may e.g. evoke thoughts of hopeful futures and work on understanding the ways in which to achieve them (Rasa et al., 2023), and to envision the different complex components that create and impact change (Ahvenharju et al., 2018; Facer, 2011; Hicks, 2003), skills deemed crucial for sustainable development of our future (Lotz-Sisitka et al., 2015). As Eleanor Roosevelt iterated in 1978, *"The future belongs to those who believe in the beauty of their dreams",* and although seemingly simplistic at first, dreaming of a hopeful future remains a concept very estranged to most students (Hickman et al., 2021).

Educational curricula for secondary education across the globe speak of the future and of teaching students the necessary skills to strive in a future society. In highlighting the importance of future skills, they fail to mention concrete ways of incorporating futures into practice (Finnish National Agency for Education, 2019; Secretary-General of the OECD, 2018; see also Poli, 2021). History is studied partially as a means of understanding past chains of events and learning from previous successes and mistakes, which brings to question the matter of why futures are not taught as a way of putting historical, scientific, and social knowledge into a context in which it can impact the world of tomorrow. Strongly tied in with futures learning, systems thinking involves an ability to conceptualize and frame topics as a part of their larger concepts, whilst understanding both details and wholes (Whitcomb et al., 2020). In contemporary competency frameworks (UNESCO, 2017), both futures thinking and systems thinking are commonly stated as key competences for future citizens and professionals. However, the inherent connections between these competence areas have not yet been sufficiently studied.

To evaluate a perspective on futures competencies and their applicability into educational settings, this paper studies a perspective in which students are given the possibility to create their futures. The paper studies the effects of futures education and future visions in developing students' systems thinking. Our focus is not on assessing students' overall systems thinking competency, but rather on exploring how different aspects of students' systems thinking are apparent in students' future visions, and how those aspects develop in a futures education course – i.e. the potential of futures education in developing systems thinking. Centred around the theme of "Helsinki in 2050", students vision the future of the capital city of Finland. Students' future visions, and the factors that construct their future city, are used to map out how students perceive the future, and how those perceptions can develop through futures education. Furthermore, this paper examines the extent to which the implementation of a futures education course impacts students' abilities to conceptualize the relationships between, and develop a systemic understanding of, societal organizations, natural biospheres, and built environments.

2.   Theoretical background

2.1.   Defining futures thinking

Unlike traditional school subjects, futures are not pre-existent concepts that can be taught through textbooks and ready materials, but rather they act as frameworks to develop thinking and awareness. Local, national, and global levels of initiative have been taken in creating multitudes of guidelines

with the aims of promoting sustainable futures, for example through increased and improved sustainability and futures education. Futures thinking is promoted through key future competencies, evoking mindset and thinking model changes, and creating awareness for and understanding of futures sustainability science and research. (see City of Helsinki, 2018; Secretary-General of the OECD, 2018; UNESCO, 2017; United Nations, 2023)

We presently live in a society created by our past, creating our future. Danskernes (1996, as cited by Remes & Rubin, 1996) defines three ideological orientations that divide society's thoughts into chronological categories based on the past, present, and future. Individuals' social and ideological surroundings shape their concepts of time, and the values that arise from those understandings of time. The various roles of the future, and how we think about it, have in turn been extensively studied in the field of futures studies. Roy Amara (1981, as cited by Aalto et al., 2022) defines a set of three core requisites to explore the field of futures studies. First, Amara (1981) defines states that the future cannot be predicted, but only imagined and speculated. Secondly, he asserts that futures are not predefined, and thirdly that societies and individuals can influence the future through their thoughts and actions. Amara (1981) emphasizes that the field of futures studies cannot be excluded from the values, principals, and ethics of the researchers in control of the thought processes.

Likewise, Valciukas and Bell (2003) state the importance and the development of the field of future studies, yet found that until the 1990's, little importance was paid to its philosophical framework. Valciukas and Bell (2003) assert that the future cannot directly be studied, due to its non-existent nature as compared with the present and/or past. They also found that the future exists within our present-day intentions and can only be studied through matters and realities which could impact the future.

Perhaps due to these abstractions, while education is by nature future-oriented, this relationship is often implicit (Poli, 2021). A notable departure from this can be seen in sustainability education: for example, GreenComp, the European sustainability competence framework, highlights "envisioning sustainable futures" as a key sustainability competence (Bianchi et al., 2022; see also Laherto et al., 2023). In GreenComp, this "competence area" involves systemic and critical thinking, futures literacy, exploratory thinking, problem framing and political agency. On the other hand, sustainability is a central concern in futures education literature (see e.g. Häggström & Schmidt, 2021). As Rasa (2023, p. 55) argues, "sustainability and futures are, in a sense, two sides of the same coin". A broad consensus exists that such thinking skills are needed: the Education for Sustainable Development Goals (UNESCO, 2017) report emphasizes the need for systems thinking, anticipation, normative reflection, collaboration, critical thinking, self-awareness, and problem solving. Combining the above competencies, UNESCO (2017) views the thinking skills needed for futures as ones that understand complexity, accept uncertainty, assess consequentiality, question normativity, and work collaboratively with aims of creating better solutions for sustainable education.

Futures thinking and the general field of futures studies are also strongly correlated with the conceptual framework of future consciousness, coined by Sande (1972). The six dimensions of future that are acknowledged and used among members of society, as defined by Sande (1972), revolve around time frames, evaluating how far into the future individuals are able and willing to see and plan. They also go on to evaluate the level of optimism and topics of interest. Likewise, Sande's (1972) study evaluated a sense of influence, agency, and power in having the ability to change the future, along with an evaluation of expectations in how individuals truly consider the future to look. The last dimension of Sande's (1972) study focuses on values that individuals indicate within their desired futures.

Revising Sande's (1972) framework, Ahvenharju et al. (2018) compile a dimensional framework of five core aspects of futures consciousness and define the components as time perspective, agency beliefs, openness to alternatives, concern for others, and systems perceptions. To narrow the scope of this study, we focus mainly on systems perceptions. Related to interactions, decisions and their consequences, and complexity, this fifth dimension of the broader concept of futures consciousness is another conceptual interface between futures, complexity, and agency. This is mirrored in the similar

concept of futures literacy, studied as reflexivity of future attitudes, studies, and pathways for action (Mangnus et al., 2021).

Although the explicit focus of this paper lies on systems perceptions in future visions, agency beliefs are considered as an over-arching motivator for the need for futures thinking in education. While agency is here not being considered as an active goal, the concept of agency in terms of Ahvenharju et al.'s (2018) definition of agency beliefs importantly motivates future-oriented educational approaches (Laherto et al., 2023; Rasa et al., 2023). As Ahvenharju et al. (2018) define it, agency in futures thinking is crucial for one's "sense of being able to influence how the future will unfold". Thus, this paper does not explore how participants make concrete efforts to achieve their futures, but rather how students perceive their impact and role on futures and the systems within them.

2.2.   Developing futures education

UNESCO (2023) states its core mission as "to build peace, eradicate poverty and drive sustainable development". All centred around future developments, the missions define the core purpose of education as an all-round tool to enable equality and sustainability. How are students to change the future, if schooling practices overemphasize historical and current knowledge and undervalue providing students with the necessary tools to imagine, develop, and create a world and society in which all beings can live sustainably and equitably? Futures education provides tools and grounding for promoting students' thinking skills towards deepened consideration of several possible futures as well as towards the impact of different parties' agency.

Although educational curricula set a national guideline for the integration of future related topics into teaching (see e.g. Finnish National Agency for Education, 2019), a multidisciplinary concept such as futures education is only concretized within teaching and learning customs. Futures pedagogy can be approached from multiple perspectives by focusing on future visions, dreaming, or practical scientific experimentation and its applicability within future scenarios, to name a few. In evaluating the need for futures-oriented education, Fitch and Svengalis (1995, as cited by Hicks & Holden, 1995, p.3) state that:

"By adding a future dimension to the learning process, we help to provide direction, purpose, and greater meaning to whatever is being studied. By integrating past, present, and future we act to strengthen a neglected link in the learning process."

Futures education has previously also been approached from the perspective of future-scaffolding skills. Levrini et al. (2021) study aspects of futures-oriented education centred around organization of present knowledge, imagination of futures, and dynamic and conscious movement within the futures related space and time continuums (Tasquier et al., 2019). Within the same international research project on teaching and developing students' futures thinking skills, Bol et al. (2023) create guidelines on for futures thinking, involving the constancy of change, reflections on the meanings of time, accepting uncertainty and ambiguity, stimulating long-term and systems thinking and curiosity, promoting imagination and plural, open thinking, as well as consciously understanding the impacts of choices and engaging with the thought-up futures. Rasa et al. (2023) go on to explore futures thinking skills in education through the lens of technology and agency, contrasting static and transformational futures and examining students' ways of complexifying future societal change.

In this paper, futures are discussed in plural, following the typical convention in futures studies. The reasoning for this is to emphasise thinking of futures as potential worlds, not a singular, predetermined world to be forecasted; after all, this is the basis of futures literacy and futures consciousness. The singular form is used when speaking of one possible future scenario or vision.

2.3. Understanding systems thinking

By understanding the interrelatedness of our systems at hand, systems thinking aims to understand full entities without breaking them down into small parts for separate inspection and analysis (Gharajedaghi, 2011). Systems thinking is to be regarded as a process rather than a result within the continuums of chaos to organization, and of simpleness to complexity.

As a core component of Ahvenharju et al.'s (2018) futures consciousness framework, system thinking is also depicted as the first central competency required from educational systems and students in order to work towards more sustainable futures. The learning of systems thinking involves the recognition and understanding of intricate relationships, along with the analysis of complexity within systems. Likewise, it involves understanding how systems and matters are embedded within themselves and outside factors in different ways. As such, the ability to cope with uncertainty and complexity of the cognitive steps required to develop one's systems thinking skills are factors apparent in different aspects of education, as implicit learning goals, guidelines, or practices. (UNESCO, 2017) Similarly, Shaked and Schechter (2019) explore systems thinking in education as the understanding and improvement of complex systems, and their examination as wholes. They highlight the crucial element of understanding interrelatedness of matters as a key focus point of systems thinking.

In connecting systems thinking to educational contexts, Hofman-Bergholm (2018) explores the extent to which the relationships of systems thinking and sustainability education can mutually create synergy in learning, emphasizing the common roles of transdisciplinary, value discussions and action and agency as key skills fundamental for meaningful learning. This allows for recognition of interconnections, identification of feedback, understanding of dynamic behaviour, using conceptual models, testing policies, and acquiring knowledge on root causes, among others, which can all be extracted as skills for broader learning scenarios.

2.4 Conceptualizing the city as a complex system

Thinking about the future naturally involves complexity: firstly, because the world is complex, and secondly because many of current societal challenges relate to complex systems from the climate and ecosystems to cities and urbanisation. Conversely, while sustainability transitions involve assessment of decade-scale projections of climate change, city planning involves future-orientedness on various levels. Cities require planning and building, anticipation of trends (e.g. immigration, household size) and reacting to newly arising issues in technology, work, transportation and so on (Toivonen et al., 2021); thus, complexities naturally arise when discussing images of desirable future cities (see Höjer et al., 2011). The teaching module that is the context for the present study tapped into these fruitful connections by bringing students to imagine the future of their city.

Some educational approaches aiming to build futures literacy in the context of the city have been reported (Toivonen et al., 2021), with results supporting the claim that thinking about futures may promote empowerment. The city is a complex system, with a rich body of literature devoted to understanding it (for an introduction, see e.g. Moroni & Cozzolino, 2019), and additional complexities emerge as societies and cities attempt to undergo sustainability transitions (Wiek et al., 2006).

The city is, at the minimum, both a place and a locus of numerous (inter)actions (Moroni & Cozzolino, 2019). Analysed further, the systemic nature of the city can be seen as consisting of multiple subsystems. Such a division of a system into subsystems is dependent on perspective and context. In this study, the city is seen through students' eyes (as opposed to e.g. city planning professionals) in the context of imagining sustainable futures. In the context of sustainability, a common and useful (even if problematic) heuristic is to separate human and "natural systems", or humans and technology (see e.g. Ahlqvist & Rhisiart, 2015); in this paper, the city is foremostly seen as an entanglement of natural systems, built and technological environments, and humans and social activity (see Research Methods and Processes).

Similar perspectives of the systemic nature of the city in relation to futures thinking are considered by Kivistö (1985). Considering futures thinking from an urban developmental perspective, Kivistö

(1985) names eight core components for analysis of today and tomorrow: society, needs, urban infrastructures, natural resources, engineering and technology, economy, livelihood and services, and other factors. This approach somewhat differs from e.g. seeing the city as like an organism (Bettencourt et al., 2007). Clearly, systems can be modelled in multiple ways. Nevertheless, the city and the body are both pedagogically interesting examples of systems; see (Tripto et al., 2017) for a study that, in the context of the body, examines the development of students' systems thinking, partly mirroring our urban approach.

3.   Aims of the study

This study aims to examine the effectiveness of a future learning course on the development of students' futures thinking and the systems perception thereof. By examining students' development of systems thinking during a continuous elaboration of future visions, we evaluate how students' perceptions of the city as a system manifest complexity in futures thinking. As there exist few studies that analyse students' futures or systems thinking developing over time, we focus on this specific issue. Namely, we describe patterns in students' thinking as they immerse in more extensive futures thinking, supported by a futures education course. With this somewhat longitudinal approach, the study aims to perceive how constructing future visions can be promoted by providing space and support for that end. The research question of this paper aims to explore an analytical approach on systems thinking and its development:

Q1: How is students' systems thinking supported by a course on visioning the city of the future?

4.   Context of the study

The data of this study stems from the *Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty* (FEDORA) research project at the University of Helsinki (https://fedora-project.eu). The FEDORA-module, developed in collaboration with Helsinki School of Natural Sciences (an upper secondary school with a science focus), engaged students in creating a sustainable future for the city of Helsinki, Finland. This experimental science course, titled "My city of the future", was attended by 11 upper secondary school students aged between 16-18 years. The course consisted of 7 lessons over the course of 2 months. The course began with an introduction into futures thinking: how it often fails to predict the future, yet one can improve and systematize one's visions, for instance, by distinguishing between thinking about possible, probable, and desirable futures.

Over the course, students worked on their visions for Helsinki in the year 2050, writing evocative, hopeful future descriptions in 4 small groups. Similar approaches of gathering students' images of the future have been explored by Angheloiu et al. (2020) and Rasa and Laherto (2022). The texts were continually challenged by the teachers as well as three invited consulting experts (smart city anthropology, values in futures thinking, energy and sustainability transitions), who posed unscripted questions based on their field of expertise regarding micro- and macro-level correlations and consequences, challenged specific decisions and actions and proposed alternative ways of thinking about and constructing future cities. Over the process, students wrote 4 versions of their future visions. The students also built timelines between today and their vision, mapping central actions to take to reach their desired future, paying special attention to systemic perspectives and the role of technology, science, and built environments in creating sustainability (e.g. energy production) and shaping the city of the future (e.g. new technologies). Pedagogical futures education methods, such as visioning and backcasting (see e.g. Laherto & Rasa, 2022; Rasa et al., 2022) were used with aims of promoting future-orientedness, process thinking, and understandings of causalities and (un)certainties.

Then, the students familiarized themselves with the publicly available "Carbon Neutral Helsinki 2035 Action Plan [CNH]" (City of Helsinki, 2018), guided by a pedagogical workshop on analysing

values and assumptions in future scenarios. After this they met with one of CNH's authors to discuss the rationale for the environmental policies of the city of Helsinki. During these activities, students compared their own thinking with official policies and contrasted the actions they wished to see taken with those currently planned or executed. Finally, guided by the teachers of the course, the students collected their written visions of Helsinki in 2050 into a small pamphlet. The course ended with a discussion panel between the students, the head of the city of Helsinki's Climate Team, and other students from the school in the audience during which the finalized pamphlet was handed over to the city. While this course was conducted in collaboration between an upper secondary school and the FEDORA research project, similar futures education courses can be conducted using the above presented methods and approaches in a non-research setting.

5.   Research methods and processes

To approach the research question of this paper, systems thinking was evaluated from a developmental perspective, focusing on how this futures education course influenced the prevalence of systems thinking in students' written future visions. The dataset examined in this analysis consisted of written future visions from four student groups. Four versions of each future vision were used to analyse the revisions occurring from the first version (V1) to the final version (V4), evaluating the content that was added to or developed from V1 in reaction to the activities of the course. The analysed excerpts thus show the alterations and additions from V1 to V4. No group removed content from V1 and no overlapping content apparent in both versions was analysed if it showed no revision between versions.

As a first step, all additions to the content of the written future visions were extracted. From these changes, units interpreted as relevant to systems thinking based on the literature above presented were analysed. As an example, consider the following two quotations. The first one, taken from V1 of Group 4, envisions the presence of new technology in personal use:

V1: "*I open my computer and quantum computer, where I develop a graphic operating software.*"

In V4, the effect of the technologies mentioned in V1 upon personal work life and workloads in general is explored, combining them with the aspects of ease of access and communication through developed technologies. This is perceived as systems thinking as the group further analyses the benefits of the technologies mentioned in V1 and how they impact human life. Systems thinking is shown through an increased understanding of the interconnectedness between humans and technology:

Added to V4: *"I did all necessary manual work on the software today, as AI does most of the code. Simultaneously I was invited for a virtual meeting ... [which] can be accessed through AR or VR glasses."*

Such revisions between the versions formed the units of analysis for the following qualitative content analysis. The revisions were coded employing the method of inductive thematic analysis (Braun & Clarke, 2006). Initial codes were formulated based on the themes apparent from the future visions, such as digitalization, employment, wellbeing, nature, which arose in the future visions verbatim. The initial codes were then revised, restructured, and formulated into inductively apparent thematic spheres, categorizing each initial code into one or more of the thematic spheres. A review of the inductive themes was followed by defining and naming the three main thematic spheres from which the students approached the city of the future: social sphere; technological sphere; and natural sphere. A comparable exploration of social, natural, and technological themes has been previously stated as a learning goal for the FEDORA -module, as well as analysed in the context of sustainable development competencies and urban geography (Moss et al., 2021; UNESCO, 2017). As noted earlier (see 2.4), these three spheres are one way to view the city as a system; these spheres were selected for the analysis due to their clear presence in the data.

The table below indicates and justifies the thematic spheres formulated through the inductive analysis of the data. They portray the types of excerpts from the visions that went into each of the three thematic spheres to visualize the meanings of each thematic sphere. The justifications provide insights into the analytical processes within this paper.

Table 1

Examples of excerpts and justifications of thematic spheres

Thematic spheres	Example of excerpts from the future visions	Justifications of inclusion
Social sphere: Society and human organizations	*"Algorithms and hundreds of employees spread awareness of municipal matters, and locals act as special experts of their own areas."* *"The idea of encouraging people to recycle using external motivators has slowly made its way to Finland. A similar concept was used in China in the 2020's, but instead of rewards, people were forced to recycle under a threat of being fined. Finland is trying to turn this idea into a reward."*	Excerpts include topics of agency and social life, looking into who has a say in causing and making change. Matters including the city and its decisions are considered in their humane approach on change through city councils and citizens. Social constructs and structures, as well as personal and social agency are included, portraying the benevolence and will for change of the people. Preliminary phase codes included i.e. employment, activism, politics, and citizens.
Technological sphere: Technology, science, and built environments	*"Initially technology was believed to fix everything: climate change, environmental crises, political unrest, criminality, marginalization, drug use etc. Countless hours and resources were invested in its development, but technology didn't magically fix everything…"* *"Technology has been deployed for peoples' benefit and aid, it is used by all, and it is not expensive. There are new ways to manufacture electronic devices with scarce natural resources. AI has been improved and it can be seen in everyday life."*	Excerpts include topics related to scientific and technological development, such as transportation, battery life and energy production. Emissions and sustainable energy production methods, alongside consideration of the city through its infrastructures and non-natural environments, such as roads and power plants, are also explored. Ponderings on the ultimate purpose of technological and scientific development are considered. Preliminary phase codes included i.e. digitalization, innovation, infrastructure, and artificial intelligence.
Natural sphere: Natural world and biosphere	*"A nearby apartment building's dark, wooden walls and extensively covering wall solar panels flicker some hundred meters away. The low sun rays fill the surrounding parks and light up the lower buildings' vernal green roofs…"* *"The most extreme nature advocates have of course been against this, but disadvantages have been compensated for by giving space for nature inside the city limits."*	Excerpts show themes of nature and climate, painting a picture of how the natural world looks. Matters consider change within the biosphere, including topics related to wildlife and sustainability, looking at an environmentalist view of the city. The role of true nature in a modern environment where nature is not the only factor contributing to the state and wellbeing of the physical surroundings is also explored. Preliminary phase codes included i.e. green sustainability, nature, and wildlife.

The excerpts in Table 1 are justified as belonging to one thematic sphere, yet some excerpts clearly contain thematical matters from other thematic spheres too. The intention of this paper is to look exactly into those overlapping areas where two or more thematic spheres meet (e.g. by combining social and natural themes). Hence, systems thinking is here analysed from a perspective of complexity between the thematic spheres as a means of evaluating systems thinking through the ability to conceptualize topics as broad entities relating to and impacting other matters. As such, systems thinking is perceived through the overlaps of the three spheres (social, technological, and natural) with the main focus on the central overlap of all three thematic spheres. The results are thus explored first through the overlap of all three categories, followed by the socio-technological overlap, then the socio-natural overlap, and lastly the techno-natural overlap.
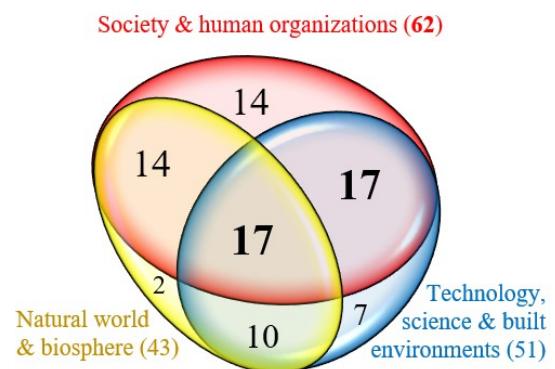
6.   Results

The students' future visions indicated deep re-evaluation of future-related values, structures, and changes through the revisions between V1 and V4. The future visions included general analysis of multiple different spheres overlapping together, as well as more in-depth examination of the dimensions of singular topics and their relations to the other thematic spheres.

The revisions made between V1 and V4 can be represented as Venn diagrams. Note that Figures 1-5 are not to scale (NTS). The Venn diagram in Figure 1, representing the city in terms of the three thematic spheres

Figure 1. Revisions from V1 to V4, all groups (NTS)

(see 5. Research Methods and Processes), portrays the revisions from V1 to V4 of the groups' future visions. Each number in the figure represents the number of text excerpts from the future visions that discuss topics relating to that thematic sphere (or of the overlap thereof). Thus, Fig. 1 gives an overview of the general revisions within all groups' future stories.

Overall, the revisions of the stories focused largely on a more systematic and full understanding of the different spheres apparent within the students' future visions. The most frequently discussed thematic sphere, society and human organizations, showed the social nature of the future visions. The societal angle indicated an understanding of the relevance of the human and social components in all dimensions of future developments.

In the following, the development of systems thinking in students' future visions is manifested in increasing overlap between the three main thematic spheres. The results are presented group by group to illustrate the qualitative differences between each group's revision process. The analysis begins with the full overlap of all three thematic spheres, and then moves on to evaluating the overlaps of two thematic spheres.

6.1. Group 1 – An environmentalist future (most revisions)

Group 1's future vision, titled "Green Helsinki", described a sustainable future built around values of environmentalism, social and natural wellbeing, as well as social awareness. The vision explored the human aspects of change and its uncertain nature by considering the agency needed to create change, and the causalities thereof. The revisions of the future vision during the course entailed increased complexity among the overlap of the thematic spheres, as can be seen from the numbers in Figure 2.

Figure 2. Revisions from V1 to V4, Group 1 (NTS)
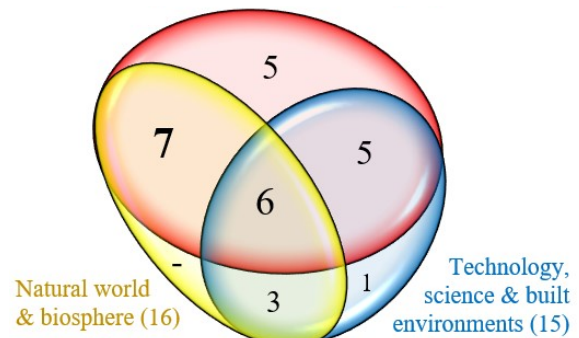
As Fig. 2 displays, the most revisions were made in the overlaps of the social sphere, with 23 excerpts. Few excerpts were considered only within one singular sphere, showing broad development of systems thinking when comparing V1 to V4. The overall future developments of "Green Helsinki" remain rather conservative, especially from the technological and scientific perspective, the downsides of which are explored alongside their possibilities. Of all groups, this vision most emphasized the need for individual and communal agency, but nonetheless agency is discussed passively, and its drivers remain unexplored.

6.1.1. Connections between all 3 themes

"Green Helsinki" shows a compilation of spheres and topics all widely relevant to society and nature, as well as technological and scientific innovation. The progression of systems thinking between V1 and V4 is apparent as seen in the overlaps of the three thematic spheres. While V1 merely speaks of sustainable energies, V4 explores a multitude of ways of sustainable energy production and considers both their benefits and challenges. V4 analyses the complexity of energy production choices and recognizes the possibility of alternative solutions, seeing energy production as a greater entity and showing possibility of its continued development in relation to its use by society and dependency on renewable natural resources:

> V4: "*The city of Helsinki has installed windmills in the windiest places around Helsinki. The electricity they produce is used to maintain beneficial services for the city of Helsinki and other citizens. ... On the other side, I see an apartment building, which as its walls covered by solar panel material. This is still not very common due to its expensive price and need for a communal decision from all the building's inhabitants. ... These solar panels are only being taken into use in the sunniest areas, but I have heard that they should be becoming more common in the near future.*"

Likewise, in V1, no topic is considered from all three spheres. V4 includes reasonings for revisions from V1 and considers the implications of these changes on personal life. For example, V4 attributes decreased environmental footprints to scientific development. The addition indicates developed understanding of the differences and similarities between one's own needs and those of the community. The same topic is shortly considered from an energy and material efficiency perspective, implicitly showing their need in scientific development. This connection of all three spheres is apparent from:

> V1: "*Apartments do not have their own laundry equipment, but apartment complexes have a communal laundry room for everyone's use.*"

> Continued in V4: "*The transition to communal laundry rooms was made to save energy and raw materials. People no longer need to buy their own washing machines.*"

6.1.2. Socio-technological overlap

The scientific and technological developments prevalent within the story intertwine with everyday life, serving to ease routine tasks while increasing their sustainability. The relationship between technology and everyday life is emphasized in V4; while V1 merely mentions a technological detail, V4 explicitly names the connection between technology and routine tasks impacting society's everyday life, as can be seen below:

V1: "*When I get my laundry in the machine, I check the contents of my refrigerator from my phone…*"

Continued in V4: "*Linking mobile phones to kitchen appliances has eased everyday life. It is possible to check the fridge or the laundry room's washing machine without having to go there.*"

Similarly, V4 explores the effects of battery technology development on society's access to sustainable and functional transportation methods. The following excerpt indicates deeper conceptualization of the impact of scientific development on society. The excerpt discusses the technological sphere from a wide array of perspectives to grasp its fundamental function in being a social necessity:

V4: "*The battery life of electric cars has been prolonged through developed technology. Nowadays, it is possible to drive the same distance with an electric car as with a tankful of gasoline. The price of gasoline has increased drastically, and a normal person can no longer afford to drive a car with a combustion engine…*"

6.1.3. Socio-natural overlap

The interactions of society and human organizations with the environment are addressed through, for example, the future city promoting sustainability through increased recycling. Emphasizing the role of governance, V4 imagines society with external motivators inviting each member of society to do their part in improving the environment, examining the role of social constructs and regulations in promoting a cleaner environment:

V1: "*Due to the development of recycling, there is almost no more mixed waste being produced. There are also more recycling points on the streets, so garbage must be carried home. The increased number of recycling points and the instruction of their use has made the environment cleaner as people know how to recycle.*"

Continued in V4: "*The idea of encouraging people to recycle using external motivators has slowly made its way … to Finland. A similar concept was used in China in the 2020's, but instead of rewards, people were forced to recycle under a threat of being fined. Finland is trying to turn this idea into a reward.*"

6.1.4. Techno-natural overlap

"Green Helsinki" combines the spheres of built and natural environments by discussing issues such as sustainable energy productions and green infrastructures. Mostly, however, the development of the relationship between nature and science can be viewed through the comparison of the group's vision to the city's Carbon Neutral Helsinki program (see next excerpt). The students' story implies that scientific development is necessary for slowing climate change and developing sustainable energies, which is linked with explicit goals on improving nature's condition. Additionally, in speaking of environmentalism and science, the excerpt recognizes the limits of the group's future vision in not being based on statistics, touching upon a perspective of the non-scientific nature of futures:

V4: "*We found many similarities in the presumptions and solutions between the CNH goals and our future. Both assumed the importance of slowing down climate change and normalizing green energy. … However, … we did not base it on statistics or precise predictions.*"

6.2.   Group 2 – A conservative, simple future (least revisions)

Group 2's future vision, "Tomorrow in Helsinki", painted a picture of an environmentalist, green future centred around developments and simplifications of everyday life. The future vision maintained a conservative stance on employing largely pre-existent technologies yet normalizing their use.

As can be seen from Figure 3, the story was revised quite marginally between the two versions. Most revisions related to social and/or natural spheres, which both had 5 revised excerpts. The values of the vision revolved around societal wellbeing, with changes and technologies employed to simplify human life. Even though the vision discusses the overcoming of the modern-day digital craze, it contradicts itself in continuing to incorporate many new technologies into the future. While some paths of change are explored, the systems perception and agency behind change remains unexplored in this future vision.

Figure 3. Revisions from V1 to V4, Group 2 (NTS)
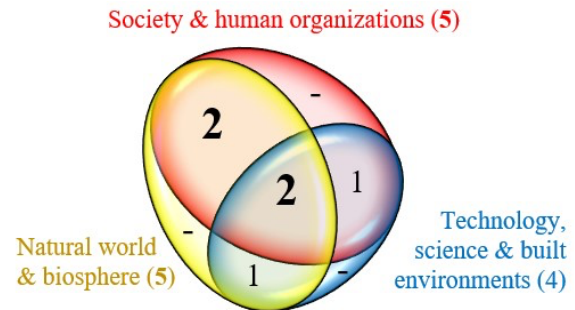
6.2.1.   Overlap of all 3 spheres

As with Group 1, Group 2's initial story (V1) does not combine all three spheres, which are later developed and visible in V4. The example below involves systems thinking in combining issues of infrastructure, nature and society, and even considers the challenging nature of city development. By recognizing the change needed in habitational structures to accommodate the green future, the story shows a deeper analysis of the change needed to achieve the future set out in V1. V1 generally discussed buildings becoming larger, but the topic below was added newly to V4. The recognition of the imperfect characteristics of change and the debate of their own future vision shows critical thinking towards own future ideologies, and also brings to light the importance of agency in achieving a communal resolution:

> V4: "*Even though space constraints have meant that buildings have been built even bigger and taller, housing complexes have become singular massive towers surrounded by large land plots. More space has been given to nature and for people to breathe between the walls. This restructuring, along with the ever-continuing urban migration, has expanded the city limits past their precedent lines. The most extreme climate activists have of course been against this, but the harm has been compensated for by giving more space for nature inside the city.*"

The relation between the implicit agency of the city and its impact on the environment is one that combines society with its surrounding nature, looking at the relationship from a perspective of built environments. Agency is in this vision explored merely from a passive perspective in which the city makes changes, yet the drivers or contributing factors behind change are not explored. The following excerpt recognizes the underlying environmental values within future society, exploring the greater value of nature against societal infrastructures within municipal governance. The excerpt in V4 adds a deepened explanation of the built, physical structures of society's and nature's cohabitation:

> V1: "*Large municipal plans have paid more attention to green routes, forcing highways and residential areas to make room for forest networks.*"

> Continued in V4: "*The entire city structure works around this 'cell network'. The city is divided into [large] residential areas that are surrounded by forest zones of at least a hundred meters.*"

6.2.2.   Socio-technological overlap

The technological developments in the story were mostly apparent already from V1, which depicted the use of technology as an aid for everyday life activities and routines. V4 does, however, also portray insights into the development of society's relationship towards technology. What is considered evident or obvious change in V1 is further explored in V4, and the story concludes that technology can have disadvantages alongside its benefits. Here, V4 also considers the value of social equity in allowing all members of society the same access to and understanding of the technologies required to keep up with environmental progress, which can be seen from:

> V4: *"Even though everything can be done on the internet nowadays, society has been able to overcome the digital craze of the 2020's and find a golden middle ground where everyone is given the possibility to be a member of society without requiring digital wizardry. Technology is a fabulous helper, but a bad host, and … we also took some time to realize this"*.

Although technology and science are highly prevalent within both versions of the vision, it states that society is distancing itself from digital dependency and working to find a balance between maximal benefit and maximal accessibility and ease of use. Technology, science, and built environments are not only presented as solutions to create a more sustainable environment, but also as a means of increasing societal agency by spreading civic awareness. Technology is shown to act as a major factor in facilitating communication and spread of awareness, accentuating the need for social equity and accessibility:

> V4: *"Algorithms and hundreds of employees spread awareness of municipal matters, and locals act as special experts of their own areas."*

6.2.3.   Socio-natural overlap

Society's ethical behaviour within nature is explored through the thematic overlap of social and natural spheres. The driving forces behind all past change, and that yet to come, is explicitly stated to be personal agency and society's agency, whilst also the city's agency remains an implicit, yet important factor of development. In this future vision, personal agency is shown through the attendance of historical preservation events. The excerpt concerning the importance of agency and actions in achieving wanted changes is a key factor showing overlap of social and natural spheres:

> V4: "*We have decided to influence and participate in the King's Road preservation event.*"

Likewise, the social sphere's overlap with nature is highlighted through the importance of voicing one's opinion and being able to act for it in matters of environmentalism. The excerpt below portrays the effects of agency and shows the positive outcome of the collaboration of differing perspectives. Additionally, the text again voices the complex nature of change through the wide array of alternatives, and of no solution being the sole good one. The general social agency in creating and promoting change is one that is highly prevalent within the vision yet remains rather implicit through the use of the passive tense rather than clearly depicting the group leading the change. In speaking of activism against the new developments regarding habitational structures, V4 explores the complex balance between social and natural spheres of wellbeing:

> V4: "*The most extreme climate activists have of course been against this, but the harm has been compensated for by giving more space for nature inside the city.*"

6.2.3.   Techno-natural overlap

Technology is widely explored from the perspective of sustainability and environmentalism, which shown through overlap of technological and natural spheres. The relationship between them is readily explored in V1, with the final only making a small addition to the text. The addition can be seen from the underlined words in the excerpt below. The addition shows slight reconsideration of the topic from V1 regarding the extent of the presence of technology within society, yet mainly V1 demonstrates how the students already consider the impact of the technological sphere upon nature before revising their visions:

V4: "*A nearby apartment building's dark, wooden walls and <u>extensively covering</u> wall solar panels flicker some hundred meters away. The low sun rays fill the surrounding parks and light up the lower budlings' vernal green roofs…*"

6.3.   Group 3 – A future of minimalism and nature (substantial revisions)

Titled "Life amidst climate change", Group 3 visioned a green future that promotes the wellbeing of nature and wildlife. The vision revolves around minimalism in individuals' future needs, promoting greater environmental goals over society's comfort. The technologies and scientific developments explored are conservative and further exemplify the green developments of the story.

As can be seen from Figure 4, the three spheres are explored fairly equally. The greatest developments occur in the broadest systems thinking, the overlap of all three spheres, with 7 excerpts. The agency behind change is explored implicitly, yet the vision emphasizes the importance of small changes within each individual's quotidian life, taking on a first-person narrative. The developments from V1 to V4 largely involve all spheres, with V4 revisiting the topics of the first version and linking them to other spheres and exploring their impacts in relation to each other.

Figure 4. Revisions from V1 to V4, Group 3 (NTS)

6.3.1.   Overlap of all 3 spheres

The development of systems thinking, and its complexity, is exemplified through the revisitation and connection of topics initially explored in V1. In the following excerpts, V1 recognizes the positive impact of the change in comparison to the situation beforehand, while in V4, the same excerpt receives a more extensive analysis. V4 recognizes the reason behind change, the social aspect of transport, the availability of shareable transport, and their functions. The revisitation of the single sentence shows how the group conceptualized the initial topic of traffic from technological, natural, and social spheres through consideration of causality and functionality:

V1: "*Traffic noise is, however, lower than it has been in the past…*"

Continued in V4: "*This is a result of the electrification of traffic, for one. I don't own a car, but I use electric rental cars that are easily available. This works quite like renting an electric scooter. The app shows you where the cars are…*"

6.3.2.   Socio-technological overlap

The relationship between technology, science, built environments, and society is, in this vision, commonly depicted through the development of technological devices to aid society and its members with everyday life tasks and activities. The text itself (see following excerpt) explicitly describes a development that occurred with the function of and relation towards technology, adding an ethical perspective of accessibility and sustainability to technological devices. While V1 discusses health and privacy as sociotechnical points of interest, V4 complexifies the sociotechnical system by including issues of ethical technology development, sustainable resource use, job markets, and even (the uncertain nature of) risk assessment. Both excerpts also discuss the safety of technological devices in relation to personal information, and V4 even adds a further challenge linked to society's attitudes towards technological development, namely that of it stealing society's jobs. By addressing both flaws and advantages of technology, the text depicts many conceptual levels of technology and its impacts on a wide array of different societal matters:

V1: "*I can check whether my food needs more minerals or vitamins from my smart watch. I can also see other important health information, and it has a connection to my home appliances.*
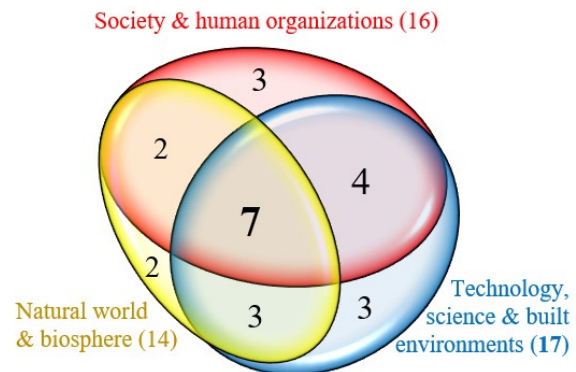
Most of my furniture is electric and can be voice-controlled, which I find very useful. At some point this was an information security risk, but it has fortunately been fixed…"

Continued in V4: "*It guides towards a healthy lifestyle without encouraging obsessive use. … Technology has been deployed for peoples' benefit and aid, it is used by all, and it is not expensive. There are new ways to manufacture electronic devices with scarce natural resources. AI has been improved and it can be seen in everyday life. … AI does some of our old work, which was not effective by manual labour. Even though it was suspected at first, AI has not taken jobs from anyone, but created more.*"

6.3.3. Socio-natural overlap

The future vision describes the relationship between social and natural spheres through depictions of society's ethical behaviour within nature. As previous topics within the text, both versions of the vision speak of the relationship between nature and society both explicitly and implicitly, however only V4 analyses the past change that has occurred to arrive at the future that is spoken of. This can be seen as the vision brings to light the humane drivers of change, and how that change must be reflected in society's behaviour. The excerpt also enforces the idea that the change has been driven forward through quality education and generational progression, while also adding the technological element as a benefit for increased communication and awareness, which lead to increased consciousness of actions. The story portrays additions to the overlap of social and natural spheres in V4 by discussing a topic area unexplored in V1:

V4: "*I am happy that more people have begun to do their best for the climate in collaboration. This has come as a result of generational change and good education. Good global connections through video calls have spread information on different ways to slow climate change…*"

6.3.4. Techno-natural overlap

In speaking of the future in a very modernized yet environmental manner, the vision combines the thematic spheres of technology and nature to create an image of scientific and technological development being leading factors in driving change towards a green, sustainable future. One of the main aspects of technology-related environmentalism is that of green energy production, that is shortly explored in V1 of the text (see below), showing the emphasis on renewable energies and recycling, and their use and impacts of smaller communities as well as on the city as a whole. The excerpt is further developed in V4, portraying development of complexity and systemics in the recognition of different renewable energy sources and the realism of their use. The extent of the reach of sustainable energies is further explored through the analysis on green public transport and its reduction in noise emissions. By bringing into discussion alternative energy sources, such as fusion, and its effects on energy production as well as its challenges in becoming a normalized energy source, the story progresses between the two versions of the stories through recognition of choice consciousness and the multitudes of options available to create the future of their V1:

V1: "*Electricity and heating in housing cooperatives comes from renewable energy sources and recycling is an important part of life in our housing cooperative and in Helsinki…*"

Continued in V4: "*Solar panels provide habitants with daily electricity and have been installed on each house. Energy can be stored for cloudy days. Traffic has become electric and does not make noise. Electricity for traffic comes from small solar and the long-awaited fusion plants. Part of the city works on fusion energy, which has decreased electricity prices considerably despite only having one power plant. Therefore, it has not yet reached markets properly.*"

6.4. Group 4 – A future of efficiency (substantial revisions with most new text)

With their future vision, "Helsinki in 2050", Group 4 explored the most drastic and complex of changes among all groups. The group partially re-wrote entire sections of the vision unlike other groups, which mostly made revisions onto the initial text. The story revolved around efficiency from the perspectives of personal ethics, transport and energy production, and social structures. With a strong per-spective on the overlap of social and technological matters, with 7 excerpts, the story mainly developed in its perceptions of technology as an all-round tool for social change.

Figure 5. Revisions from V1 to V4, Group 4 (NTS)

The initial story was already largely environ-mentalist, and hence the development of systems thinking is least explored through the nature category. The described developments are complex to the point of discrepancy and lack of causality within the text, indicating the changes visioned could have been even further developed. The story involves social-ist and communist social structures, yet within its social changes, the agency behind them is considered merely implicitly. This contrasts with Group 3, for which technological change seemed to be the primary point of entry to an imagined future; for group 4, change was primarily socio-political.
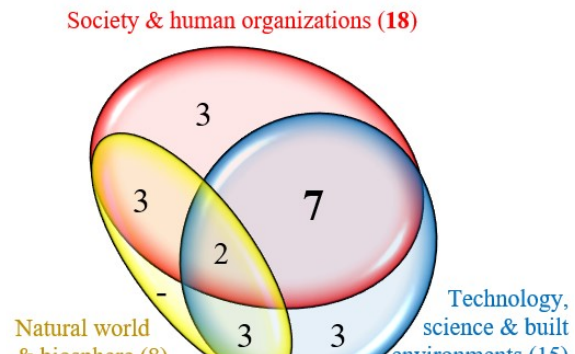
6.4.1. Overlap of all 3 spheres

It is only in V4 of the text that all three spheres are deeply considered among the same topical excerpts (see example below), showing increased complexity even on a surface level. Combining the themes of technology, material efficiency, and community, V4 recognizes the changes needed to achieve the future described, focusing on the societal aspect of true need as compared to use. The technological development is considered alongside its effects on society, limiting the use of devices for necessities, not recreational use. The change is reasoned through the excessive materialism caused by unnecessary use of technology, in turn causing excessive production and emissions. In contradicting the role of technology present in other excerpts of the story, the following excerpt from V4 thus incorporates issues concerning the sustainability of technology from both a societal as well as environmental perspective, which were unexamined in V1:

V4: "*Technology exists, but no longer in recreational use. It is used for communication and in some cases work. … The issue with AI technology is its material aspect, as it consumes natural resources, production is untransparent and unjust, and it must be produced constantly due to its short lifespan. The solution was to make devices tools of community, with smaller batteries, lighter operating software and changeable parts.*"

6.4.2. Socio-technological overlap

"Helsinki in 2050" highlights the societal aspect of technological development, shedding light on the need for critical thinking in achieving the full benefit of technology, without excess use, produc-tion, or reliance. V4 adds the perspective of the possible downsides of technology, emphasizing the importance of recognizing changes in attitudes and allowing for alternative solutions when a previous plan has proved ineffective:

V4: "*Initially technology was believed to fix everything: climate change, environmental crises, political unrest, criminality, marginalization, drug use etc. Countless hours and resources were invested in its development, but technology didn't magically fix everything…*"

The critical perspective takes a step back from technology-oriented future narratives regarding society and its needs and wants. V4 proceeds to explore the equality issue of technological development. Starting off from a technological perspective, the excerpt below continues to explore the importance of social equity brought on by the communicative aspects of technology and their accessibility. The sense of fairness and community is further explored through the addition of increased collaboration and decreased competition between producers of technological products and services. Simultaneously, the excerpt makes a statement on the structures of the economy and its businesses, implicating pure collaboration as a better means of production than competition, later stating the profit remains the same. Although the aspect is not fully explored, it aims to consider a further, complex perspective of technology in relation to the people that make and use it, depicting a grand increased in systems thinking related to how technology intertwines with the creating society:

> V4: *"It has been realized that all matters, excluding vital and just life and communication, only spark momentary joy, and have nothing to give. Hence all joint ownership production technology firms collaborate, as it improved the work and product. They plan collectively without competition. Devices are made for people, not profit. Otherwise, devices would become jaded, and the hard work would be lost."*

6.4.3.   Socio-natural overlap

The development of systems thinking within the vision concerning society is not only linked to community and social wellbeing, but also to the central values of the story, environmentalism, and sustainability. The society of the story is shown to take agency in promoting an environmentally friendly lifestyle and environment, creating a sense of social pressure for all citizens to act sustainably. In adding a social taboo on unsustainable transportation methods to V4, the vision depicts the importance of choice consciousness among all of society, emphasizing the importance of community in leading each other towards a common goal:

> V4: "*A social ban has been placed on private car travel … due to resources and the contamination of cars.*"

The display of social ethics within nature is further explored through the city's and society's agency within the city environment and the greater world, as can be seen through the excerpt discussing immigration and climate change. While stating the failure to achieve sufficient change in time, the excerpt speaks of the failure as a communal doing, touching upon the need for communal actions in creating change. In speaking of the destruction of nature due to society's previous actions and the inability to undo them, the vision also approaches the importance of social togetherness in times of natural disaster. The developments within the systems thinking related to human ethics and nature consider different perspectives of natural change, bringing to light the destructive realities caused by society's inability to act in time and enforcing a sense of societal responsibility over natural wellbeing:

> V4: "*Helsinki's population has grown only through immigration, as many areas were destroyed by climate change. We were not able to halt it in time, despite efforts.*"

6.4.4.   Techno-natural overlap

Systemic development in this vision can also be analysed through the overlap of natural and built environments, exploring how the visions show evidence of interconnectedness between the environment and science. V4 (see excerpt below) discusses the impacts of changes to the built city environments upon the wellbeing of nature. The excerpt explores the reduction of car traffic upon the decreased need for asphalt roads, allowing for the increased prevalence of dirt roads, in turn improving the natural water cycle. In exploring the effects of built environments upon the conditions of the nature, the vision depicts the effects society has, directly or indirectly, upon nature, emphasizing the idea of technology, science, and built environments existing within nature, not above or alongside them:

> V4: "*Car travel and its pollution have decreased. Therefore, many asphalt roads have been converted to sand, as they no longer have polluting … traffic. Fixing asphalt roads is expensive*

and releases bitumen into the environment, so their upkeep was no longer wise. With sand roads, urban runoffs were deployed as they were only needed to guide waters into the right places on asphalt roads. Ridding urban runoffs enabled a natural water cycle in the city, influencing vegetation area wellbeing and decreasing minor flood risks."

7.   Discussion

In examining the developments of students' future visions during a futures education course from the perspective of systems thinking, this study took on a constructive approach in viewing futures thinking through hopeful futures. The course focused on evoking hopeful futures thinking as a means of directing the students' ways of thinking towards the possibilities of solutions to ongoing challenges. While the focus in no means aimed to yield purely positive future images, the notion of hope within the course ties in strongly with the motivation of developing students' agency beliefs to create better futures rather than live in perpetual climate and future anxiety. The revisions of the students' future visions gave insights into how they were able to revisit topics and reconceptualize them in a more interconnected, complex structure. The development of systems thinking between the two versions of the groups' future visions encloses multitudes of topic areas and analytical perspectives. Through them it can be observed how the interconnectedness of the topics within the stories grows and portrays an increased understanding of the complexity of social, natural, and technological systems and thematic spheres.

The development of systems thinking was in this study analysed from the perspective of the city as a whole made up of three thematic spheres: society and human organizations; natural world and biosphere; and technology, science, and built environments. The analysis here portrays the development of the students' abilities to conceptualize complex matters on both detailed and abstract levels. The results bear resemblance to those of Rasa et al. (2023), who analysed complex change in students' views of the future and identified varying extents of systemic thinking. However, their study did not examine the effects of futures learning on these conceptions. Thus, our study points towards the potential of futures education in addressing some of the concerns raised by Rasa et al (2023).

In showing most development in the overlap of all three spheres, students showed development of complete systems thinking through increased understandings and analyses of the relations between human agency as a driver of change, technology, and science as tools to build more sustainable societies, and the constant impact of the biosphere on all actions and decisions. Similarly, Hofman-Bergholm (2018) concludes the improved recognition of interconnections to be a central benefit of the systems thinking approach. The development involves understandings of how technology can act as a tool, yet only when used with precautions and limitations, in reverting to a more natural, green environment. Furthermore, the development of systems thinking links to how all change is dependent on social agency, which is shown through notable developments within the thinking models employed by the students during the futures education course.

In general, all groups together most emphasized the social sphere, second the technological sphere, and least the natural sphere. The focus on social aspects of the future is one that adds onto the findings of Levitas' (2013) studies. The number of excerpts speak to the development of the students' future visions throughout the course, and as such show the spheres most central within each groups' visions. As Fig. 1 displays, most revisions were made in the overlapping themes, speaking to the broadened conceptualization skills of the students. With all groups put together, the most frequently apparent overlaps were those of all three spheres, and the socio-technological sphere. As previously indicated, systems thinking is here perceived through the interconnectedness of the three thematic spheres, and as such the full overlap of all three spheres shows significant reconsideration of the topics within students' future visions and revision of their implications upon other topics.

Additionally, sustainability and environmentalism were central themes promoted to varying extents in all groups' future visions. Linked in with aspects of social agency, the needs for sustainable technological development and the relationships between natural and built environments, environmental

matters permeated all texts. Adding on to Hofman-Bergholm's (2018) findings on the importance of a systems thinking approach in sustainability education, the results point to the fact that sustainability cannot be excluded from the themes of society and technology. Even though the natural sphere is the one with least revisions between V1 and V4 of all groups together (43 excerpts), it is the sphere most tightly interconnected with the other thematic spheres. Merely two excerpts were considered from only the natural sphere, whilst all others intertwined natural matters into their social and/or technological contexts. This points to the developed understanding of the role of nature as a complex, intertwined entity impacted by, and impacting, the areas of social and technological development.

The revisions showed more focus on the natural sphere, indicating deepened understandings of how natural environments, resources, and biospheres impact the thematic spheres of society and technology. Technological themes were present in each group's vision from the initial version, indicating the current importance of the topic area, as the course did not need to externally raise the importance of the technological sphere. One central finding of this paper is that the revisions showed how students were able to interconnect the technological topics present in V1 to their impacts on society and the natural environments, an aspect equivalent to the findings of Rasa and Laherto (2022). The intertwined nature of the thematic spheres was only present in the V4s of each groups' texts, pointing to noteworthy revisions of technological topics during the course.

Whilst the general line of development of systems thinking was similar between groups, each group portrayed a slightly different emphasis within their stories. Group 1 and 4 had most development within the social sphere, group 3 within the technological sphere, and group 2 within both the social and the natural sphere. Within the same futures education course, groups were able to elaborate their visions based on their individual topics of interest of concern, which is visible through the differences in emphasis of the thematic spheres. The finding is positive in considering the narrative nature of the results. The aim of the futures education course was in no means to impose a certain vision of the future upon students, but rather to promote futures awareness, critical thinking, and agency for change, and allow students to dream and conceptualize their own futures.

By further looking into the thematic spheres and topics discussed within the individual groups' visions, the study found that even in a small sample size study, student groups wrote visions that differed entirely from others. Emphasizing the concept of futures as undefined, pluralistic scenarios, each group wrote a personal future vision whilst attending the same futured education course as the other groups. Group 1 showed development of systems thinking by attributing the decreased environmental footprints to scientific development, exploring the relationship between science and nature in creating their tomorrow. Group 1 also emphasized the role of governance and civic responsibility, showing a deepened understanding of how ultimately it is society and its individual people who enforce the change needed for a better future. As for Group 2, whilst not revising their story as much as other groups, they touched upon a meta-analysis of their own text, looking for faults and imperfections within their future changes. In speaking of climate activism against their future city, Group 2 showed deep consideration of the nature of humanity being made up of its differences. Furthermore, Group 2 visited the topic of artificial intelligence being employed for communication and spreading of awareness, indicating increased complexity between the roles of society and technology. Group 3 had a strong stance on the pathways leading to change, showing systemic consideration of what changes society must make in order to improve the state of the environment. Whilst promoting topics of social activeness and environmental wellbeing, Group 3 approached their story from a very technological perspective, creating a vision of a complex society in which technology has been tied into most aspects of life. Contrarily, Group 4 approached the changes in their future vision from a socio-political perspective, examining how a change in social and governmental structures creates their tomorrow. As with Group 2, Group 4 also explores criticism towards their own vision in discussing the downsides of technology and in exploring how they intend to solve those issues. Whilst each group visioned an entirely different future city, all groups explored the interconnectedness of their topics, as well as new ones, through the revisions of their texts.

It is also noteworthy that at times, students' efforts in visioning complex entities and understanding their roles in the city came through as discrepancies within the visions. The group that made

most revisions to their future, which already from the beginning was more on the radical side of changes, Group 4, explicitly stated that their futures revolved around humane and natural values. They stated that the technological craze had been overcome and that the role of technology in people's lives had substantially decreased. An analysis of their vision, however, showed that technology pertained a fundamental role in their city of the future. Technological developments were intricately woven into areas of environment, transportation, and even basic everyday matters such as automatized streetlights. The discrepancy in itself portrays development of systems thinking in that students recognize the multiple areas of impact that technologies have, even if their vision is not able to completely conceptualize the full interconnectedness of all topics within the thematic spheres. Rubin (2013) explores similar topics regarding students' confusion about matters related to the future in a time of constant change. Likewise, the result adds to the findings of Jacobson (2000) in showing that problem solving of complex systems, such as the city here, is not immaculate among novice-level systems thinkers, such as the participants of this study.

As this study was conducted within one futures education course in one local upper secondary school, it must be noted that the results cannot be generalized to all students due to the small sample size of the data. Likewise, the future visions themselves are not representative of a larger sample, but the systems thinking apparent in the revisions of the stories can be taken as an indication of the forms of fundamental skills that can be strengthened through futures education. As such, this paper indicates possible results that can stem from employing futures education pedagogies and challenging students' future visions during a futures education course. Further larger scale and broader studies would be needed to create a generalizable, representative dataset.

The present findings provide illustration of how futures education may contribute to learning systems thinking. Specifically, the results capture some of the dynamics between futures and systems thinking in a suitable context (the city). Still, this small-scale study is not generalizable – and furthermore, futures education courses are not set to produce uniform visions of the future. This approach should be expanded to explore how futures education can address systems and their complexities and interrelatedness, alongside a deeper consideration of agency beliefs towards creating more sustainable futures. Likewise, this study could be complemented by research on the long-term effects of the futures education course. A discourse analysis on the same data could also provide deeper insights into singular future visions and their depictions of the city of the future.

Nevertheless, the findings of this study show that students' understandings of the complex systems and their interrelatedness developed during the course, showing positive predictions for the success of similar futures education courses. It would also be scientifically relevant to study the perceptions of certainty and uncertainty towards the future of the same, or similar texts, to understand how futures education can shape not only students' ways of thinking systematically and conceptualizing systems, but also analysing how strongly students believe in their desired future. Methods of analysing uncertainties of futures, such as those employed by Maier et al. (2016), could provide deeper insights into students' perceptions of plausibility and agency. Similar to the examination of uncertainties, this study serves as a robust foundation for studying aspects of sense-making and strange-making of the future. Previously explored by Bol and de Wolf (2023), their approach on this data could yield more results on perspectives on anticipation, empathic thinking, and imagination.

8.   Conclusions

Overall, the resulted development of systems thinking in students' future visions during the futures education course provided new insights into the implications of such futures education courses: the development of systems thinking sheds light onto the progressive benefits of allowing, encouraging, and challenging students to work to build and solve a future in which they would wish to live. In merely a short-term course, students' understanding of how future perceptions can change from abstract ideologies to concrete plans, as per Rajala and Cole et al. (2022), deepened. The finding differs from the current realities in schools and curricula (see e.g. Finnish National Agency for Education, 2019), that

overemphasize skills and knowledge that students will supposedly need in the future, yet undervalue thinking about and understanding that future that they are heading towards.

By visioning a hopeful future and backcasting to concretize the steps between now and an imagined future, this study adds onto that of Rasa et al. (Rasa et al., 2023) in showing how students were challenged to better conceptualize the need for agency and action in creating change. Students showed development of complete systems thinking through increased understandings and analyses of the relations between human agency as a driver of change, technology and science as tools to build more sustainable societies, and the constant impact of the biosphere on all actions and decisions. In understanding the steps needed to achieve a possible future, and in conceiving their interrelatedness among matters of society, nature, and technology, visioning the city of the future was shown to develop both topic-area specific understandings. The development sheds light onto the importance of cross curricular skills and on vast development that can occur even in a short-term course. Futures thinking in schools not only allows students to understand the possible futures of the world, but also evaluate their own thinking skills and models. Systems thinking and futures education can promote an understanding of an individual's role within an ever more complex world and foster the perception of their ability to impact the future. By understanding the complex roles of society, nature, science, and technology, students can begin to concretize their hopeful futures into actions in aims of creating a more environmentally and socially sustainable future.

Keypoints

- The study takes an approach on analysing education *about* the future with aims of exploring the development of cross-curricular competencies. The study explores students written visions of a hopeful future from the perspective of the city of the future.

- Through a qualitative thematic analysis, this study finds that futures education expands students' systems thinking. The development of students' future visions during a futures education course emerges understandings of complex systems, interrelatedness, and causalities related to futures.

- The development of systems thinking is shown through the increased interconnectedness of social, natural, and technological thematic spheres that make up the city of the future. Students' systems thinking mostly developed in the complete interconnectedness of all thematic spheres.

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Ethics Approval and Consent to Participate

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