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Young people's technological images of the future: implications for science and technology education

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Abstract

Modern technology has had and continues to have various impacts on societies and human life in general. While technology in some ways defines the 'digital age' of today, discourses of 'technological progress' may dominate discussions of tomorrow. Conceptions of technology and futures seem to be intertwined, as technology has been predicted by experts to lead us anywhere between utopia and extinction within as little as a century. Understandably, hopes and fears regarding technology may also dominate images of the future for our current generation of young people. Meanwhile, global trends in science and technology education have increasingly emphasised goals such as agency, anticipation and active citizenship. As one's agency is connected to one's future perceptions, young people's views of technological change are highly relevant to these educational goals. However, students' images of technological futures have not yet been used to inform the development of science and technology education. We set out to address this issue by investigating 58 secondary school students' essays describing a typical day in 2035 or 2040, focusing on technological surroundings. Qualitative content analysis showed that students' images of the future feature technological changes ranging from improved everyday devices to large-scale technologisation. A variety of effects was attributed to technology, relating to convenience, environment, employment, privacy, general societal progress and more. Technology was discussed both in positive and negative terms, as imagined technological futures were problematised to differing extents. We conclude by discussing the potential implications of the results for the development of future-oriented science and technology education.

Keywords: Images of the future, Science education, Technology education, Student perceptions, Future-oriented science education

Introduction

Modern technology has had and continues to have an impact on human life and civilisation that is hard to overstate. While technology in some ways defines the 'digital age' of today, discourses of 'technological progress' may dominate discussions of tomorrow. Meanwhile, predicting the 'real future' and figuring out how to do it well is a field in itself, and experts within and outside specific technological fields project a wide range of predictions for the coming decades: technology has been predicted to lead us anywhere between human extinction [10] and planet-sized self-aware computers [32] within the timescale of a century, with more cautious predictions forecasting a 'third industrial revolution' by 2030 ([16], p. 33). Understandably, hopes and fears regarding technology may also dominate the images of the future for our current generation of young people (see, e.g. [3, 36]).

Obviously, the fact that developments in science and technology can have great desirable and undesirable societal implications is reflected in science education. This element is central to research currents such as STSE

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(science, technology, society, environment—see, e.g. [6]), SSI (socioscientific issues—e.g. [49]) and the various visions of scientific literacy (e.g. [45]). Interestingly, however, these socioscientific leanings rarely address explicitly the temporal aspects of socioscientific thinking. Thus, even if local and global SSIs 'are all related to important aspects of our future' ([44], pp. 2–3) and environmental education should address 'Where do we want to go?—knowledge about alternatives and visions' ([28], p. 331), the connection to futures thinking is often unaddressed when contextualising science as societally relevant. For example, the focus of STSE has been applying science and technology in social (more or less real-world) contexts, understanding the sociocultural embeddedness of such activity and exploring holistic, value-centred approaches to evaluating technoscientific issues [39]. These aspects of scientific literacy certainly have a 'time component', but seem to lack a more nuanced relationship with futures. This oversight seems to reflect a general pattern in education (see, e.g. [24]).

Understandably this 'blind spot' has been criticised in the futures field: according to Gidley & Hampson [22],

> *[s]chool education seems to be mostly stuck in an outdated industrial era worldview, unable to sufficiently address the significance and increasing rapidity of changes to humanity that are upon us. An integrated forward-looking view should, now more than ever, be of central importance in how we educate. Yet there is little sign that – unlike corporations – school systems are recognising the true value of futures studies.*

While the field of science education has seen some recent initiatives for developing students' futures thinking [29, 34–36, 38, 41], much work remains to be done in communicating between the two fields. One approach to strengthening the foothold of futures thinking in schools may be identifying practical contexts for future-oriented education and joining with natural 'allies' within the range of educational fields [23], or formalising the concept of 'futures literacy' in education, eliciting students' images of the future, and supporting their agency [24]. A further goal may be formalising relevant capacities to also enable evaluation of learning processes and outcomes, where constructions such as 'futures consciousness' [1] may prove useful.

Meanwhile, young people's future thinking has been analysed in several studies (e.g. [3, 15, 43]), revealing both pessimistic and optimistic future outlooks. Such studies also support the notion that technology is strongly associated with imagined future worlds—a connection embodied in science fiction, which arguably could also be called 'technology fiction' or 'future fiction', demonstrating a strong association between the concepts. Within futures studies, this link may seem obvious (see, e.g. the role of technology in the 'future archetypes' of [27]), but it is underrepresented in science education literature; students' hopes, fears and expectations regarding the future are rarely addressed.

There may also exist a discontinuity between the approaches taken when addressing socioscientific thinking within education, and those taken when studying young people's perceptions of the future. Namely, societally oriented science education research and practice may tend to be based on individual issues [6] and case studies, while research on young people's perceptions of technology may look at technology more generally [7].

Thus our goal in this paper is to explore the following question:

> *What kinds of technology and what desirable and undesirable impacts of technology are present in upper-secondary school students' images of the future?*

Specifically, we examine a set of Finnish upper secondary school students' essays that describe imagined future worlds, set in years 2035 and 2040. We analyse what technologies are present in these essays, what aspects of the world and human life are affected by technology and whether these effects are framed as positive, negative or in neutral or conflicted terms.

Our goal is to diversify the meaning of the term 'technology' in (young) people's futures thinking by providing an exploratory study on expectations, hopes and fears associated with specific envisioned technological developments or the processes of technologisation in general. Finally, we conclude by discussing potential implications of the results for the development of science and technology education, and the potential of using socioscientific and sociotechnical issues as a context for futures thinking in education.

Background

Definitions and rationale

In this paper, we examine the role of technology in upper-secondary school students' images of the future. By images of the future we mean 'snapshots of the major features of interest at various points in time' ([42], p. 14). Images of the future do not necessarily contain 'an account of the flow of events leading to such future conditions' (Ibid., p. 14); this temporal perspective would turn an image into a *scenario* (which are more commonly explored in futures studies and also in future-oriented science education—see, e.g. [35]).

Images of the future are widely addressed in futures studies. However, as they exist in people's imaginations and are by nature complex, they are difficult to fully pin down. Perceptions about the future are an integral part of one's worldview [36], and at least in the case of nonexpert futures thinking, they can be expected to lack some systematicity. Imagined futures are often inconsistent [30] and can perhaps be better understood as reflecting the present [9]. An example of inconsistency is the common finding of a disconnection between optimistic personal and gloomy global futures [15, 43, 47].

In the case of images of *technological* futures, one's understanding of technology is naturally a component, but only one of many. To quote Zeidler et al. [49], p. 360, 'knowledge and understanding of the interconnections among science, technology, society, and the environment (...) do not exist independently of students' personal beliefs'. For our purposes, no attempt to separate these components is necessary: our goal is to give voice to the image that emerges from these influences.

Defining *technology* is something of an arduous task, partly because the meaning of the word seems to vary greatly between contexts—it is a 'slippery term' ([5], p. 7). Thus for example the 'T' of STS (Science and technology studies) may be different from the 'T' of STEM (science, technology, engineering and mathematics). The students who wrote the essays that form the dataset for our study were asked to address the role of technology in their image of the future, and no theoretical definition was provided with this prompt. We expect students to have relied on some commonsense meaning of the word, and for the purposes of our study, we consider technology to be related to *artefacts, tools, methods and systems that are based on the application of knowledge specific to STEM subjects.* We expect this meaning to correspond to some extent with students' thinking.

This study uses a unified view of science and technology education, or scientific and technological literacy (see, e.g. [33]) that is typical in current trends of interdisciplinary and societally oriented science education, or STEM education (see, e.g. [12]). As a clarification, we do not wish to convey the idea that the relationship between science and technology is obvious and uncomplicated (see, e.g. [4]). However, this is a context-dependent issue: firstly, technology experts and technologically literate citizens are expected to gain much of their education within science education, and secondly, the boundary between science and technology tends to disappear (or lose some of its meaning) in societal and future-oriented contexts [26]. Thus, studies of students' images of technological futures can be expected to provide insight into the expectations, opportunities and sociotechnical thinking that will eventually be reflected in both the practice of technology experts and the actions of nonexpert citizens [31].

Perceptions of (technological) futures

Research on young people's futures thinking has shown that science and technology are typical ingredients in young people's dystopian views [13] but also central to their hopes of sustainable or otherwise progressive futures [15, 36]. According to Cook ([15], p. 528), young people may generally feel 'a loss of faith in the notion that humanity is progressing towards a positive future'—and thus society is 'due for another break through' with the help of technology.

Similarly, according to a study by Heikkilä et al. [25], Finnish people aged 16-20 seem to feel positively about technology amid a general trajectory of societal decline—while being reserved towards many areas of technology or new technologies in general, and feeling mostly optimistic about their own futures. In their study, young people's images of the future involved robots, entertainment technology, home automation and new ways to travel, but also considerations against using robots as workforce, and in favour of ecological energy production and general 'high technology'. It is notable that while such attitudes towards technology may be vague and inconsistent, they are nearly universal: in a nationwide survey, the increasing significance of technology was the most common future belief for Finnish 15- to 29-year-olds [37].

In Angheloiu et al.'s [3] paper, young people (ages 16-17) were found to mostly see an optimistic future where technology is strongly embedded in people's daily lives, improving their quality of life and creating sustainability. However, optimism was not universal: some youth were found to e.g. fear environmental or health crises that would give rise to totalitarian regimes. In fact, the authors (p. 5) recognised the motif of "trade-offs between tech that makes our lives convenient at the price of 'ethics and morals'". This corresponds with the common discourses of technology as a 'double-edged sword' or 'Faustian bargain' (see, e.g. [14]). Across many outlooks, young people in Angheloiu et al.'s [3] study shared worries of accelerating inequality and increasing social isolation, also caused largely by technology, with similar findings reported by e.g. Kaboli & Tapio [30].

At a population-wide scale, van der Duin et al. [48] analysed Dutch adults' views of the year 2040 (similarly to the present paper). They focused especially on societal, economical, environmental and technological issues. In the last category, questions of robotisation, digitisation and biotechnology were specifically addressed in both likelihood and desirability. Perhaps unsurprisingly, Dutch people (88%) believe science and technology to greatly advance in the next few decades, while their attitude towards technology was almost evenly split between positive, neutral and negative. Expectations of 'making life easier' and 'having a positive impact' were reported: examples include electric transport and automatised household tasks, but to a lesser extent also advances such as teleportation and colonisation of other planets. The respondents' technological worries related to cybersecurity, privacy, behaviour prediction systems, robotisation, diminishing human contact and 'unnatural' outcomes, among others.

At an even wider scope, Special Eurobarometer 419 [18] found that Finnish people and Europeans in general (aged 15 and over) expect technology (or 'science and innovation') to contribute to many important issues in the near future. These included health, jobs, education, skills, environment, energy supply, security and inequality. Interestingly, with the exception of inequality, in all of these issues, Europeans expect 'science and innovation' to contribute more to progress than 'people's actions'. In a similar manner, general opinion on futures was more divided than the role of technology in futures, which was seen in mostly positive light (opinions were most divided on cybersecurity). This connects well with Cook's [15] notion of technology as a 'refuge of hope'.

More recently, in Standard Eurobarometer 94 [19] it was found that Europeans' general future perspectives are somewhat gloomy, even if inconsistent: future generations are expected to face more difficulties, and nations are seen as going downhill, even if these feelings coexist with 'confidence in the future' (p. T118 in Data Annex).

Most people indeed believe that 'science has a positive impact on society', and especially young people feel informed with technological developments ([17], p.5). Technology is expected to make life easier, more comfortable and healthier, even if the rapid pace of development is perceived somewhat negatively by the majority. However, as Kerschner & Ehlers [31] have pointed out, these attitudes seem to be diversifying, and Eurobarometer surveys may address this issue too superficially. To quote Kerschner & Ehlers (p. 139):

> *In the past any diversion from unquestioned optimism was interpreted as a bad sign and attributed to the public's ignorance. Today it is often welcomed as a sign of an increasingly emancipated public.*

Accordingly, we emphasise the point that critical attitudes are not simply 'luddite pessimism', nor are hopeful attitudes always 'sci-fi romanticism'—and attempt in this paper to give adequate voice to both critical and enthusiastic views.

Some scholars have also argued that attitudes towards technology may be different from attitudes towards any specific area of technology [7], or that there is no single direction in which sociotechnical transitions can take us, or metric by which to judge them [46]. In this paper, we address both general and specific views of future technology with the explicit intention of diversifying discourses of sociotechnical conceptions.

Thus there is considerable even if in some ways limited literature on how people perceive technology and technological futures. Similar questions have been a matter of some discourse in educational research as well, even if not as exhaustively. For instance, Clough [14] has noted that the pedagogies around the nature of technology should address how technology may impact behaviour, thinking, privacy and values among other facets of life, Hodson [26] has discussed connections between technological and scientific literacy and sociopolitical action, and Aikenhead & Ryan [2] have long before suggested researching students' conceptions on the many impacts technology has. Equipping students with tools to understand how socioscientific and sociotechnical issues shape their lives is certainly one of the goals of modern science education. However, as Facer ([20], p. 99) has argued,

> *[r]hetoric about young people's 'ownership' of future socio-technical change is a familiar part of much educational and political discourse. This does not, however, translate in practice into a meaningful dialogue with young people about the sorts of futures they might wish to see emerge.*

We wish to argue that while emphasising the societal relevance of science and allowing students to practice socioscientific argumentation in the classroom is worthwhile, these questions should be adequately linked to students' perceptions of the future, and specifically their own future.

Method

Data collection

The data for this paper consists of 58 student essays. These were collected from 57 Finnish upper-secondary students from schools in the Helsinki region. 20 essays were collected in 2018 with the title 'A typical summer day in 2035' and 38 in 2019 with the title 'A typical summer day in 2040'. One student wrote two different essays in two consecutive years.

In addition to the topic, students were given the instruction to describe what kind of general and technological environment they would like to live in (i.e. a preferable future—see, e.g. [8]). They were prompted to approach this task by addressing the topics of what one's life is like, the problems one and one's communities face, the opportunities one perceives, what items and objects are present, what kind of the city or country lives in and the social life one leads. Finally, they were asked to fill in sentences beginning with 'my dream is', 'my dream place is/has', 'my ideal world is/has', and 'my biggest fears and concerns are'.

The data collection took part within the European Erasmus+ project 'I SEE' (2016-2019) [35]. The essays were collected as prerequisites for volunteers attending experimental courses, i.e. before any teaching intervention took place. All essays were translated into English before analysis, with student names replaced with pseudonyms. All these students (or with underage students, also their guardian) gave written consent to participate in the research.

Analysis

In order to analyse what technologies and effects of technology are present in students' images of the future, we employed thematic analysis [11] with inductive coding. We began by cataloguing passages in the essays based on the subject matter. A total of 385 passages relating to technology were identified, forming the set of our analysis units. Typically, an analysis unit would be one to five sentences long, and describe one (although sometimes more) technology, and one (or more) effects of the technology in one continuous argument. Many passages were also found to discuss technology generally without further specification.

The effects of technology were identified strictly by what was addressed in the essays. For example, a unit that mentioned 'greener air travel' was seen as discussing 'transportation technology' with effects relating to 'the environment' while another passage that described casual commuting between Finland and Italy was seen linking transportation technology to increased mobility. As these examples also demonstrate, by 'effect of technology' we mean aspects of life, society and the world that are influenced in some way by technology or technological change. The focus on 'technology' and 'effect' is employed here for analytic simplicity: for some students, technology seemed to drive change, but for some, expectations of sociotechnical transformation were also drivers of technology. Thus 'effect' covers a range of causal systems. By definition, every unit of analysis discusses either one or more specific technologies or technology in general. However, in some cases, no clear effects were addressed within the text. An example is the short unit 'I own an electric car'.

These categories were formed inductively based on multiple rounds of coding, which included some redefinition, combination and subdivision of initial coding categories. The specificity of each technology or effect (e.g. coding both greener aeroplanes and electric cars under the technology code 'transportation') was done by the authors with the intention of creating codes with meaningfully different contents.

Finally, we separated the analysis units into three categories, based on whether the effects of the technology were phrased in terms that convey these effects as desirable, undesirable or whether they are discussed in neutral terms. To be precise, we checked each unit against the following criteria:

Positive: Changes described or framed as mostly positive—improvement, desirable effects, solved problems

Neutral: indifference; neutral descriptions; positive and negative aspects balance out

Negative: Changes described or framed as mostly negative—problems, reluctance, disequilibration

The authors negotiated codes for unclear units until consensus was found. In addition, every unit was checked against coding criteria to eliminate mistakes and inconsistencies. The codes with less than eight occurrences were also merged with other, similar codes. Finally, to structure the presentation of our results, the final set of technologies, as well as the set of effects of technology, were grouped into 5 and 6 sections respectively (see Tables 1 and 2).

Results

General observations

A somewhat wide range of images of the future presents itself in our data. Ranging from highly imaginative to conservative, and simplistic to highly detailed, the essays cover many societal transformations and systemic interactions within society, but focus mainly on technology and the routines of adult life. Derek (all student names given here are pseudonyms) imagined a post-scarcity world, Andre thought that 'most problems are solved' in 2035, and Damian imagined himself in the future, missing the 'old days' before overtechnologisation. Some students described worlds where climate change is 'solved', while in others' images increasing climate issues serve as a looming backdrop. Quite interestingly, a 'typical summer day' in a *preferable* future also included a wealth of worries related to technology.

Almost all students described in some detail the technological advances apparent on a day in 2035 or 2040. For some students, these were creative, fantastic or narratively distant (ranging from a hub of sky-high glass tubes that serves as public transport to living on a Mars colony ruled by AI). For others, advances were more modest, such as longer-lasting smartphone batteries. Interestingly, a few students stated or implied that

Table 1 Technology codes that emerged from the analysis, grouped into categories. In addition, illustrative examples, number of occurrences and percentages of positive and negative framings are given (any remaining occurrences were coded as 'neutral')

Category	Code	Example	n	% pos/neg
Everyday devices (39%)	Transport, travel	*We have shifted to electric cars*	54	72 / 0
	Smart home	*Overnight, robots would have cleaned and organised my apartment*	25	88 / 0
	Computers, phones…	*We would have powerful and light computers*	21	76 / 14
	Wearables	*People have smartwatches (…) to collect various types of information about our bodies*	18	44 / 0
	New interfaces	*With the help of the restaurant's facial scanner, the payment process is effortless*	15	73 / 7
	VR, entertainment tech	*many people prefer to live in the virtual world in their own homes*	15	53 / 35
Digitalisation & automation (31%)	Automation, robotics	*Manual labour is almost entirely done by machines*	38	39 /32
	Internet, digitalisation	*Data security on the internet has improved*	32	41 / 25
	Communication tech	*It's easy to get in touch with friends and family through 3D video calls*	28	61 / 7
	AI	*My biggest concerns and fears include the speed at which artificial intelligence evolves*	24	71 / 4
Technology in general (29%)	Technology in general	*I would like to live in a place with highly advanced technology*	111	62 / 18
Production (10%)	Energy production	*The development of renewable energy sources has been rapid*	26	85 / 4
	Production, recycling	*Many of our everyday items would be made from recyclable materials*	13	85 / 8
Miscellaneous (14%)	Medicine, biotech…	*various cancers and HIV, were cured by quantum chemistry*	23	73 / 18
	Space, geoengineering...	*Mars would be home to the first human settlement located on another planet*	8	75 / 0
	Science instruments	*Advanced technology would be found (…) in state-of-the-art laboratories*	7	100 / 0
	Others	Ex. 1 *Nuclear and hydrogen bombs would also still be a problem* Ex. 2 *Customs control may [use] new types of devices*	14	64 / 14

technology will likely not impact their lives: Thomas likened new innovations to useless things like 'electric nailclippers', while Robyn focused solely on changes in social issues such as human rights and (non-technologically) sustainable lifestyles. We also noted that some students addressed, even in length, aspects of the social construction of technology, such as risk-benefit analysis or democratisation of technological development. Such meanings students gave to technology in their essays will be presented elsewhere [40]—here we focus on the types of technology and the fields of influence, as described above.

Future technology and its effects

Overview of the analysis

Various types of technology were identified from the data, ranging from general discussion of technology to smartwatches and from fusion reactors to neural implants. All the technology types in our coding are shown in Table 1.

In essence, discussions of technology typically focused on everyday devices (e.g. phones, cars, household machines), technological systems and broad categories of technology (e.g. vague or general use of the word 'technology', energy production systems, large-scale automation of service jobs). Elements resembling typical science fiction scenarios were found to be relatively rare: these included advances in robotics, artificial intelligence and a few mentions of spacefaring or brain-computer interfaces. The full range of technologies present in students' images was thus found to be somewhat conservative, perhaps reflecting the given time span of two decades, or perhaps due to the context of imagining one's own future.

Despite students' restraints in describing more imaginative or fantastical technological changes, the effects of technology show notable variation. Technology was usually seen as affecting everyday convenience (often specifically household activities), the structure of job markets and environmental issues. Technology was also associated with social life, equality, health and privacy, or connected with larger issues such as overtechnologisation or general progress (for a full list of our effect codes, see Table 2).

As the examples selected for Table 2 demonstrate, technology was depicted influencing the world in both positive and negative ways, again showing considerable range: at one extreme are nuclear wars and 'loss of humanity', at the other are happiness and 'a better future'. In total, 244 units were coded as positive, 55 as negative and 86 as neutral. However, it is notable that students were instructed to focus on a *preferable* future. Thus, while valence counts are reported in Tables 1 and 2, the

Table 2 Effect codes grouped into categories, with examples, number of occurrences and percentages of positive and negative framings

Category	Code	Example	n	% pos/neg
Everyday life (40%)	Convenience & everyday life	*robots will make our daily lives easier*	53	78 / 2
	Interaction, social life	*there is technology that helps me live a socially active life*	33	65 / 18
	One's surroundings	*there are screens or reflections of ads and news everywhere*	24	67 / 4
	Chores, housekeeping	*Unless I wanted to, I would not have to do anything to maintain my house*	19	90 / 0
	Time-saving	*Thanks to artificial intelligence and automation, people also have more free time*	12	92 / 0
	Mobility, location-independence	*it would be easy for the inhabitants to move from one place to another*	12	83 / 0
Society (28%)	Equality, rights, divisions	*wealthier nations will benefit more from new technologies (…), inequality will increase*	24	50 / 38
	Privacy, cybersecurity	*privacy loss (…) could result from large-scale digitalisation*	17	24 / 53
	Stability, safety, security	*Travelling in robotic vehicles can be risky*	13	62 / 23
	Embeddedness, cultural shifts	*technology becomes integrated into everyone's lives in the future*	11	36 / 27
	Availability of information	*All the information about what 's happening around us is very real-time*	10	40 / 10
	Politics, power, democracy…	*society's main problems relate to legal matters revolving around IT software*	10	40 / 50
	Economy (exc. job market)	*Finland has developed into a global leader in the technology sector*	9	78 / 22
Work & skills (23%)	Work, job market	*machines have replaced people in most jobs*	44	50 / 27
	Own career	*I work in a health care technology company*	18	89 / 11
	Skills	*we need more knowledgeable people who can (…) programme instructions for the robots*	17	47 / 35
	Education	*High-quality education is available to everyone (…) through distance learning courses*	8	50 / 25
Wellbeing & enjoyment (16%)	Physical wellbeing, longevity	*my clothes may need to cool my body down or protect me from UV radiation*	18	89 / 0
	Need to 'unplug'; tech-free spaces	*It is important to me to not spend my entire life surrounded by machines*	14	14 / 29
	Passivity, tech addiction, mental health	*society's major concerns include people becoming passive consumers of entertainment*	11	23 / 69
	Happiness, quality of life	*technology gives me more ways to fulfil myself (…) and be happy*	8	78 / 0
	Enjoyment, hedonism	*many applications and objects that bring the greatest possible enjoyment to everyone*	11	92 / 0
Sustainability & risks (17%)	Environment	*The technology would be used to replace polluting things in our society*	52	92 / 2
	Catastrophes, major risks …	*potential nuclear wars and (…) using technology to (…) create large-scale disasters.*	14	7 / 71
'Direction of progress' (9%)	Progress, hope, universal good, etc	*humanity would have evolved towards a better future with the help of technology*	17	88 / 0
	Overtechnologisation	*with the advancement of technology and electronics, we might lose our humanity*	16	19 / 50

goal of our exploratory study is to analyse qualitatively various themes identified in the dataset.

Let us now look at how the technology and effect codes interconnect. Our analysis revealed a somewhat complex web of connections between technology, impacts of technology, and the desirability of such developments. This is illustrated by Fig. 1, a Sankey diagram of the entire coded dataset. As one notices by looking at the diagram, due to constraints of space we cannot in this paper give examples of every type of connection in the data. Instead, we will present some key findings in the following sections, moving from more obvious roles of technology (practical uses) to more

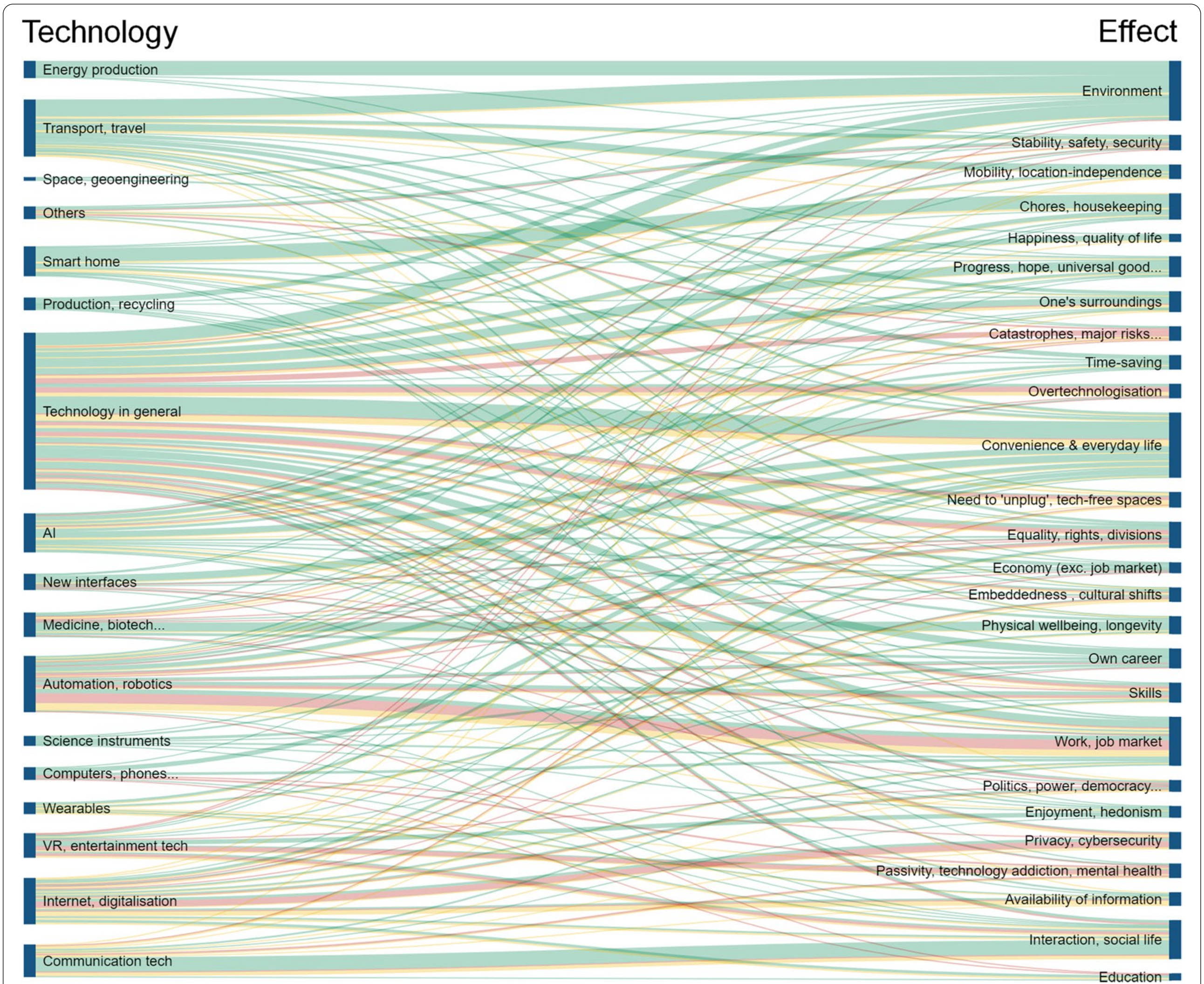

Fig. 1 The connections between technologies and their effects. The width of the lines indicates the frequency of the connection. Green colour indicates positively, yellow neutrally and red negatively depicted change

complex ones (societal challenges and the systemic effects of technology).

Everyday life and relationships

Some of the connections are rather unsurprising, such as the idea that smart home technology has a positive effect on everyday convenience. In fact, the 'easier everyday life' of the future is one of the most salient features in our data. These imagined technological advances were related to handing tasks such as household chores over to robots, paying purchases with one's phone more often, faster commuting and self-driving cars, wireless phone chargers or a more general expectation of adult life that is not limited or burdened by mundane tasks.

> *Laptops would also be paper-thin and easy to carry with you. (Willow)*

> *Unless I wanted to, I would not have to do anything to maintain my house. In the modern world, everything revolves very closely around technology. Life is easy, because everything that is 'unpleasant' is handled by artificial intelligence. (Andre)*

While in students' visions technology often makes life easier and frees up time for more fulfilling activities, self-actualisation was rarely seen as stemming directly from technology. Similarly, technology was depicted providing an easy way of managing one's social life, but it could not replace social activity not mediated by technology. In fact, some students saw technology as a force driving people apart: either by creating a culture of superficial acquaintances or by allowing people to retreat into lonely virtual worlds. However, the technologies students proposed as future ways of communication were typically not radically different from technologies that exist today.

> *I would like to live in a technologically advanced environment where a single lightweight, easy-to-carry device could be used to accomplish a lot of things. (...) one downside to this may be that our social life is likely to become more distant. (Oliver)*

Environment

Alongside hopes of easier everyday life, other technological impacts that were seen positively were those relating to the environment. As Fig. 1 clearly shows, the connection between technology and environment was overwhelmingly positive. This was sometimes discussed as 'solving' climate change, and sometimes simply as a more incremental move towards greener technologies:

> *Climate change and other environmental problems have already been solved successfully, and all energy production is renewable or utilizes, for example, fusion power. (Manuel)*

> *Electric cars are used for long-distance travel, since they are ecological. (Claire)*

Technologies relevant in overcoming environmental unsustainability included energy production, recycling, production and transportation, but also geoengineering. While some students regarded fighting climate change as a hopeless battle against indifference, in most students' essays climate and sustainability issues were discussed as either 'solved' problems or tackled by ongoing action:

> *However, new technologies have solved many climate-related problems, such as carbon dioxide and sulphur emissions. These can now be removed from the atmosphere to the surrounding space in a controlled way. (Natalie)*

> *Despite technological development efforts, climate change is still a very relevant problem, and we will probably have had to create global technological solutions to slow it down. (Lily)*

Not all efforts to mitigate climate change were based on new technologies—other kinds of sociotechnical change, such as banning cars and increased demand for green energy production were also mentioned. However, while students often discussed climate change mitigation in their essays, almost none of them imagined any technologies related to adapting to a changed climate, with the following exception:

> *While the worst of the predicted climate catastrophe is yet to come, these new automated fans that follow along with you are just not enough. (Isabella)*

Employment, equality and privacy

While students saw potential in technology impacting environmental issues positively, in many other societal issues technology was linked to worries and fears. These included questions of privacy, the risks and vulnerabilities of digital systems, people becoming passive consumers of entertainment or losing the ability to concentrate, increasing social inequality (often caused by the automation of entire professions) and sometimes an AI catastrophe, technological weapons or misuse of mind-reading technology. For example, in Nina's vision, society was still recovering from 'the big data leak of 2037', a nationwide data security catastrophe, and in Derek's future, people 'spend their time brainlessly staring at the screen'.

A large portion of the essays depicted a society dealing with impending or ongoing mass unemployment of people in automated service or manual work sectors:

> *There are not so many jobs these days, so many people are working in research and technology, just like me. Many of the professions that required human contact in the past have been replaced by robots that do the work as well as humans, except they are cheaper and more efficient. (Zelda)*

Typically more intellectual jobs were expected to remain viable, including those in science, design, cybersecurity, innovation, programming or undefined 'new professions'. In these visions, working life was often portrayed as competitive and hectic, with a constant need to keep up with changing demands:

> *Through social media, you are in contact with every organization in the world, and every organization is in contact with you. If you know what is expected of you (...) you can be very successful in this world. (Aurora)*

Many students foresaw technology causing inequality in the future. This effect took place mostly through the unemployment in large work sectors discussed above. Students also expressed fears that technology could marginalise less educated people or 'widen the gap between the rich and the poor and enable the latter to be oppressed on a global scale'. In fact, even in more positive visions, the connection between technology and equality was sometimes phrased in ways that seem to imply concern:

> *I want to live in a place where technology benefits everyone, not just those who are more fortunate than others. (Mel)*

Divisions, overtechnologisation and progress

Technology (and the increasing embeddedness of technology in human life) was also connected with what appear to be *technomoral* questions. In other words, technology was not only seen benefiting various stakeholders or communities differently, but also as an issue where values and beliefs surface, creating societal and cultural tensions and polarisation:

> *By 2040 (...) technology used to study the brain and the functional systems of digital devices will be tightly integrated, and information technology can often be used just by thinking a few thoughts. (...) Our society is divided into groups: those who see nothing bad or unpredictably dangerous in this technology, and those who oppose it completely. (Aurora)*

Curiously, similar mind-reading technology was described in solely positive terms by other students, but in these cases it was contextualised as easy-to-use interfaces for smart devices. This illustrates how some students seemed to concentrate on new possibilities, while others (even in a 'desirable future' framing) seemed to be more trade-off oriented, especially in larger, society-wide contexts. A similar pattern is seen in the way individual innovations were often discussed as positive developments, while forecasts of larger technological trends were more often paired with some worry. This is most clearly reflected in discourses of 'overtechnologisation':

> *The biggest fear is that with the advancement of technology and electronics, we might lose our humanity (…). (Brian)*

> *(...) I do not want to live on technology's terms in a world that is chock-full of technology. (Emilia)*

Similar developments are possibly implied by students who emphasised that they wanted to live in cities where greenery has 'not been replaced', or surrounded by non-technological objects. In fact, many students had written about a balance between technology and nature (or humans), whether in conjunction with overtechnologisation or not. Relatedly, students pictured futures in which one needs to consciously 'unplug' from time to time to retain connection with other facets of life:

> *It is important to me to not spend my entire life surrounded by machines, even though they make my life easier. (Mel)*

Thus, technology was associated with a dangerous allure that individuals or humankind as a whole should guard against. However, the general fear related to the direction of humanity's technological progress is in stark contrast to ideas centred on possibilities and progress. Several students expressed general trust or hope in technology being a part of a better future, or even a sign of humanity's success:

> *I am sure we will live in the era of amazing technology. We can expect huge breakthroughs in physics and information technology that can benefit everyone. The place where I want to live is a place where you can clearly see the development of technology and humanity as a whole (...). (Malcolm)*

> *I would wake up in the morning and, instead of waking up to the news of how humanity is failing, I would wake up to news of new technology being invented. (Lianna)*

Lianna's comparison between humanity's failings and new technology—as well as Malcolm's pairing of development of technology and development of humanity—seems far removed from fears of overtechnologisation or loss of humanity. Furthermore, Lianna described only exponential positive progress, while in Malcolm's image of the future technology also creates unemployment. This exemplifies how students' images of technological futures seem to reflect views of technology in general, hopes and fears of the overall future of humanity, and mediation between such elements.

Systems perspectives and complexity of sociotechnical change

The causal links between technology and effects also showed diversity. A contrast can be seen, for example, in two quotations provided earlier: Aurora's complicated narrative of computer-brain interfaces stirring cultural polarisation and Manuel's straightforward recounting of solving climate change. Technological change was not always seen influencing the world in immediate and instrumentalist ways, but also through systemic, higher order effects. This is a key observation and is well worth another example. Caden saw the future becoming even more globalised via technology-driven location independence and explained this process in some depth:

> *As communication and traffic systems evolve, I believe that travelling and exchanging thoughts and information across the world will be very common in the future. As a result of globalization, cultures and states will become more and more alike in the future, citizens will continue to move from place to*

> *place, and states will no longer exist in their traditional form. (Caden)*

These somewhat 'historical' narratives were constructed around both positive and negative developments. On the clearly positive side, Lex imagined technology creating prosperity which allows universal basic income, ushering in a new age of people working for passion rather than money. However, for some students the intended use of technology and its direct effects were overshadowed by collateral damage to society, as in this rather dystopic vision:

> *(...) our society is unstable and environmental problems are a major problem, but people are not interested, because they are locked into their own bubbles. In their own virtual worlds. Sometimes I miss the old days. (Damian)*

This quotation was extracted from a relatively rich context: the rather unrecognisable sci-fi cityscape in Damian's vision and his portrayal of himself as a protagonist who is 'ready to change the world' (through his scientific career, in a time where most jobs are automated) is a powerful representation of the range of meanings science and technology may take in young people's futures views. For some students, these meanings seemed to cause some dissonance that was sometimes addressed or resolved in the essays, for example by weighing the excitement of robot waiters against the perspective of the unemployed service staff. In the case of conflicted feelings towards technology, some students reflected on their positions either by identifying as their future self or explaining their hopes and fears from the present perspective:

> *I am grateful for all the inventions and technologies that I get to use today. But at the same time I am a little worried – for example life is no longer as private as it used to be. In the past, I might have been somewhat shocked if I had seen the present-day society. I talk a lot about this with my friends and family, and they, too, completely agree on both the opportunities and concerns. (Claire)*

> *I believe there are both good and bad aspects to technology, and I cannot imagine a future where only one or the other would occur. (Natalie)*

Conclusions

Discussion of results

In our study, we examined Finnish upper-secondary school students' images of desirable technological futures. As Tables 1 and 2 and diagram 1 summarise, students' futures thinking shows a somewhat wide range of technological futures thinking. While students' images involve an arguably limited perspective of areas of technology that may be relevant for their futures, these technologies, and technology in general, were associated with a fairly wide range of effects. Of these effects, most salient were hopes of easy day-to-day life, advances in environmental issues, and the automation of jobs.

Students' views correspond to a large extent to the results of earlier studies on images of the future. Technological points of interest that students examine in their essays included robots and automation, smart homes, transportation and energy (cf. [25, 48]), technology for sustainability (cf. [3, 15]), the role of technology in everyday life (cf. [3, 17, 48]), inequality and isolation (cf. [30, 48]), privacy and cybersecurity (cf. [18, 48]), and technology as progress as opposed to fall or stagnation (cf. [15, 25]). Our study builds on these results firstly by not predetermining what technologies should be addressed in imagined futures, thus allowing respondents to construct a vision based on their own ideas, and secondly by explicitly addressing the difference and the associations between technological change and its societal or individual effects. Furthermore, by utilising a written assignment as the basis of the study, we were able to elicit students' own sense-making of these connections both in the context of specific technologies that they associated with their own future, and the wider trend of technologisation.

Our results demonstrate how some students quite readily problematise sociotechnical change, identifying moral questions, considering trade-offs, stakeholder perspectives and systemic long-term effects. Technology was given both instrumentalist and unproblematic meanings (such as increased convenience) and much wider and more abstract meanings such as general progress or a dangerous trajectory leading to overtechnologisation of life. Interestingly, positive effects were commonly attributed to incremental improvements of existing technologies or specific new innovations, while the larger trends of automation, digitalisation and technologisation were seen in more conflicted terms.

These elements in students' essays form a somewhat multifaceted picture of the roles technology may take in young people's futures thinking; no single element captures the multitude of these roles and meanings. For example, it is not straightforward to determine whether students' images of technological futures are overall 'positive' or 'negative'. Given that students were asked to describe the kind of technological future they would like to see, it is worthwhile to note the frequency of both negative expectations and the 'Faustian bargain' discourse. On some level, many students seem to share the belief that positive and negative aspects go hand in hand. However, it is equally worthwhile to note that 24 student essays did not contain any negative effect codes, and of these eight discussed only positive effects. For example, Violet's technological future featured smooth everyday life, the tools 'to cure deadly diseases', an atmospheric cleaner, fusion power and superhuman AI with endless uses.

The difference between purely positive and mixed images of technological futures could be attributed to variation in students' views, but it is equally arguable that the difference may stem from students focusing to different degrees on 'preferable' (as opposed to 'probable' or 'plausible') futures—i.e. whether students focused on possibilities or critical perspectives. It is partly because of this interpretative ambiguity that we have here focused on analysing the 'micro-level' roles of technology in images of the future rather than the overall sociotechnical futures (i.e. each essay as a whole), with the intention of capturing the diversity of students' ideas, hopes and fears about technology.

Limitations of this study and opportunities of further research

As the writing prompt given to students asked for a description of a desirable future, the strong leaning on positive effects of technology does not necessarily signify technological optimism. Similarly, asking students to think of a *typical* day may have primed students to think primarily of familiar (i.e. conservative) future worlds. However, perceptions of the future are complex, and any singular image is only a component of a larger whole. Further research is needed on the way individuals navigate various or even contradicting ideas about the future that they may simultaneously hold. As a related challenge, the essays analysed here can be seen exhibiting varying degrees of perceived 'realness' to the students. For example, one very short essay described the author living on a Mars colony ruled by an AI system. For us, this entry seemed unserious, possibly indicating some challenge in imagining (or writing about) one's actual future. Thus, further research may need to gauge how likely students believe their imagined futures are to actually manifest.

Our study tentatively indicates that there are multiple layers of the entanglement of technology and futures that may exist in young people's thinking: the everyday devices and general technological landscape of one's life, various positive and negative societal transformations related to technological change, and general trends of technologisation that indicate whether humanity is 'headed in the right direction'. Further research is needed to identify and operationalise how images of the future are constructed with relation to specific and general beliefs, hopes and fears about technology. An additional key issue unexplored by the present study is the sources from where young people draw elements of their images of the future.

Accordingly, there is much room for similar work to be carried out with various focus points. Here we have operated on the level of individual connections between technology, its effects and their desirability in order to reveal some of the complexity of students' images of the future. Further studies could investigate students' beliefs regarding the agents that drive sociotechnical change, the values they associate with these changes (see, e.g. [21]), and how they connect larger trends to their own lives and their own agency. For this end, this paper lays groundwork for further work carried out in the FEDORA project to discuss the desirable effects of technology in the light of students' values [40].

In addition, it may be worthwhile to examine what kinds of (science) pedagogies could meaningfully address students' future views. Such initiatives have been carried out, for example the I SEE project (2016-2019) (see e.g. [35, 41]) and the FEDORA project (fedora-project.eu). The implications of the present study for science education are discussed in the following section.

Finally, we note that the sampling is very likely not representative of Finnish youth, as the participants of the study were volunteers enrolling for an additional science course on futures thinking. Thus, they were likely to be interested in science subjects and think positively about scientific ideas. Our study may underrepresent views of the future that are common to other cohorts. The frequency of various perceptions among different age groups, genders and cultural backgrounds also demands broader samples and is left for further investigations.

Implications for science education

As our results demonstrate, images of the future provide a rich perspective into the interaction of students' futures thinking and sociotechnical thinking. However, as we have shown, images of technological futures differ in many ways from each other. Therefore, science education oriented towards socio-scientific issues (SSIs) [49] should not address the future as a separate SSI but integrate it in a variety of scientific, social, cultural, ethical, environmental and economic aspects. Our results on the breadth and connectedness of students' sociotechnical future visions give support and contribute to the holistic type of SSI teaching suggested by Rundgren and Rundgren [44] and invite science education researchers and practitioners to develop tools to help students connect their technological and socioscientific reasoning with their future outlooks and their futures thinking skills.

Such tools have already been developed for science classrooms in a few initiatives during the past two decades [29, 36, 38]. In Europe, future-oriented science education has been advanced in the I SEE project. The research presented here lays the groundwork and contributes to initiatives of this type by building a more nuanced understanding of students' images of the future with relation to science and technology.

For science educators, a particularly interesting phenomenon seen in the data reported here concerns the depth of students' spontaneous socioscientific thinking. In vastly different ideas such as Caden's technologically united globe, Aurora's polarising neurotechnology and Damian's world of VR-induced indifference, a seemingly limited area of technology has effects that range well beyond the immediately obvious. This illustrates how complex and multilayered one's future perception can be: even a singular and tightly expressed image of the future may contain a wealth of interacting beliefs and ideas. When constructing an image of the world students went beyond addressing simplistic cause-effect socioscientific discourse and engaged in thinking of systemic, higher order effects of sociotechnical change.

Thus, our results imply that constructing images of the future can be a pedagogically rich and meaningful task that taps into the transversal learning objectives in science curricula. While such future-oriented pedagogies face the challenge of addressing the inherently unknowable, in the context of science education they can also harness students' curiosity about the future, their existing futures thinking skills, and the prevalent idea that scientific and technological ideas may come to determine the future to a great extent. As Facer (2012) [20] has argued, framing the future as 'lived' and 'local' seems to encourage students to think meaningfully and critically of sociotechnical change. This approach could also address the need to help students contextualise the 'core knowledge' of science, which is a focus of STSE and SSI education (see, e.g. [6]), to promote scientific literacy (see, e.g. [45]), and to give students a more nuanced representation of the nature of technology (see, e.g. Clough et al., 2013).

Our results also brought out a variety of technology-related hopes and fears that students may typically hold. In order to foster students' agency, science and technology education should find ways to address and elaborate such feelings and escape simplistic visions that may be either dystopian, utopian or static. Teachers should help students perceive both opportunities and pitfalls in technology and, for example, problematise the naïve expectations of 'technological fix' for sustainability challenges. Relatedly, the diversifying attitudes towards technology should be linked to a belief in the malleability of (sociotechnical) futures through informed agency.

Our study offers evidence that upper-secondary students can be quite capable of engaging in futures thinking in a manner that combines creativity, value-based evaluation, a systems perspective and scientific literacy. However, for the purposes of science education, and the goal of understanding young people's futures perceptions, it may prove useful for educators and researchers to distinguish between different types of sociotechnical transformations, such as complex systemic transformations (relevant from the SSI perspective) and more incremental and limited technological change (e.g. from a problem-solving, instrumentalist perspective).

Finally, it seems reasonable that practicing formulating images of desirable futures is necessary to acquire the skills needed for technology experts' reflective practice (see, e.g. [4]), or steering technology towards sustainability. After all, '[w]hen students' images of possible futures are elicited, valued and acted upon students are empowered to work towards a future they would prefer' [36]. This goal requires further exploration of young people's conceptions and pedagogies inspired by futures studies to evoke and evolve these conceptions—a task that we hope to have demonstrated to be feasible, fruitful and necessary. However, for this purpose there needs to be much more dialogue between the fields of futures studies and educational research.

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Authors' contributions
TR carried out the data analysis and was the main contributor in all parts of the manuscript. AL planned and lead the data collection in the I SEE project and framing the research in the FEDORA project and helped with writing the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials
The dataset analysed during the current study is available in the Zenodo.org repository, https://doi.org/10.5281/zenodo.5517595.

Declarations

Ethics approval and consent to participate
Participating in the study was voluntary. All participating students (in the case of underage students, also their guardian) gave a written consent to

participate in the research. The need for an ethics approval for the study was waived.

Consent for publication
The participants have consented for essays written by them to be used and commented on in the study.

Competing interests
The authors declare that they have no competing interests.

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