



Future scenarios to introduce sustainability-related Socio-Scientific Issues in science education

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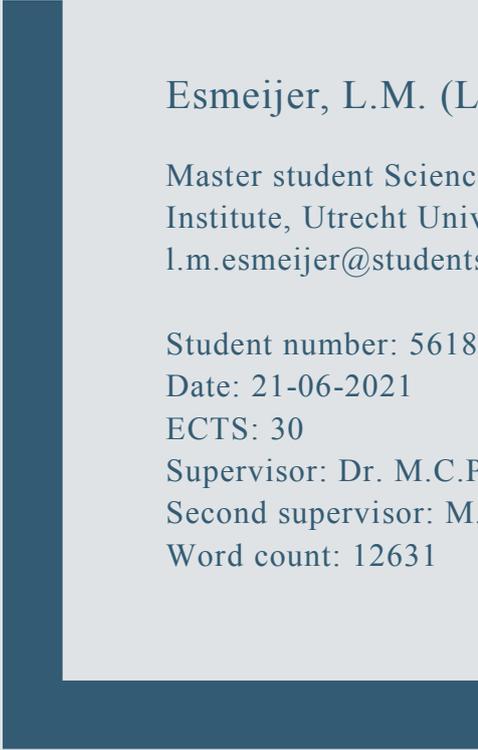
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Abstract

This study explored the design and educational potential of six future scenarios for introducing sustainability-related Socio-Scientific Issues (SSIs) in secondary science education. It is an important aim in science education to have the competence to deal with these issues as a thoughtful citizen, described as a component of scientific literacy. SSIs are controversial issues that have no clear-cut answers and include scientific, societal, and personal elements. Therefore, well-informed opinion-forming and decision-making on both the scientific and the social aspect and thinking about future possibilities is required when dealing with these issues as a thoughtful citizen. Introducing sustainability-related SSIs in the classroom is challenging because of their interdisciplinary and complex content and their future character that is often being experienced as abstract and difficult to comprehend. Presenting them in a narrative way using future scenarios can provide a concrete and realistic view of an SSI and connect the complex content and future character to students' daily lives. This can evoke students' engagement and motivation, stimulate future thinking about sustainability on a deeper level, and encourage students to ask questions and explore their own and others' emotions and values required to negotiate these SSIs. Six future scenarios were designed based on criteria derived from literature. They covered different themes such as energy policy, biodiversity, and food production. The scenarios were read by Dutch lower secondary high school students (N=24, 11 females, 13 males; average age 12.3 years old), and they were interviewed both individually and in focus groups (12 individual interviews and three focus groups of four students) to explore their reactions to the scenarios. Participants' reactions to the scenarios were analysed by distinguishing questions, emotions, values, and types of reasoning. Findings show an educational potential for all six future scenarios to introduce sustainability-related SSIs in science education, for they evoked questions, emotions, values, and reasoning among the participants, required for opinion-forming and decision-making when negotiating these issues. It is recommended to carefully select one scenario or to combine two or more scenarios for further research on the development of teaching and learning methods for implementing future scenarios in education.

Keywords: Scientific literacy, Citizenship education, Socio-Scientific Issues, Sustainability education, Future thinking, Future scenarios

Introduction

The current global environmental crisis involves a variety of complex sustainability issues concerning topics such as energy policy, water management, biodiversity-loss, and food waste (Gutierrez, 2015). The competence to engage with science-related issues and concepts of science as a thoughtful citizen is described by PISA as a component of scientific literacy (OECD, 2018, p. 100). This definition emphasizes the importance of being competent to practice scientific knowledge in real-life situations. This is an important aim in science education both in The Netherlands and internationally (DeBoer, 2000; Sadler, 2004b). For this, students should be able to participate in public debates on sustainability issues and make well-informed decisions using scientific knowledge. Since these issues contain scientific, societal, and personal components, they are considered socio-scientific issues (SSIs). These are controversial issues that have no clear-cut answers and usually include an ethical component. Such issues often involve insight into normative aspects, such as underlying values and moral reasoning, as they are socially and personally related (Ratcliffe & Grace, 2003; Sadler, Barab, and Scott, 2007). Since the current environmental crisis involves many sustainability-related SSIs, students need to be able to use scientific, societal, and personal knowledge and values for effective participation in current public debates and valid decision-making (Sadler, Barab, & Scott, 2007). For that reason, science education can well inform and prepare students by not only focusing on knowledge, but also on skills like clarifying and communicating values required to negotiate these complex SSIs.

The involvement of scientific, societal, and personal themes without clear-cut solutions or answers, makes it complex and challenging to approach sustainability-related SSIs in education (Sadler, 2004a). Besides the interdisciplinary and complex content, the future character of sustainability-related issues challenges the engagement and future thinking skills of students. Sustainability-related SSIs frequently involve long-term impacts, such as melting of glaciers, diseases, droughts, and food scarcity. These effects and risks are often being experienced as abstract and difficult to comprehend (Jones et al., 2012). This challenges students' engagement and motivation to negotiate SSIs. If education offers possibilities for students to explore possible and preferable solutions to both current and future sustainability-related challenges and stimulate thinking about future possibilities, students will more easily develop competences such as future thinking. Future thinking can provide opportunities by building possible, probable, and preferable future scenarios for students to reflect on when incorporated in SSI-focused science education (Jones et al., 2012; Buntting & Jones, 2013). By doing so, they can reflect on their own values as well as on those of others. Clarifying student values about sustainability-related SSIs improves communicating values and moral reasoning. This is required for well-informed decision-making and engages students in active and responsible citizenship. Raising student awareness of the societal and personal values about sustainability-related SSIs creates opportunities for informed opinion-forming and decision making about these complex issues.

A lot of research has been done on understanding, managing, and conceiving engagement of students on negotiating SSIs in education (Dawson & Venville, 2010; Knippels, Severiens, & Klop, 2009; Sadler, Barab, and Scott, 2007). Students can be stimulated to communicate their point of view by implementing current SSIs in education

that are relevant to students' daily life and considering the moral or ethical problems associated with sustainability-related issues in the classroom (Sadler, 2004b; Jones et al., 2012). Numerous studies indicate that teaching SSIs encourages students' interest and motivation (Sadler, 2009), fosters decision-making and moral reasoning (Sadler, 2004a; Sadler, 2009; Zeidler, Applebaum, & Sadler, 2011), and can provide context to support scientific literacy (Zeidler, Sadler, Simmons, & Howes, 2005; Zeidler, 2015; Bencze et al., 2020). Furthermore, Mei (2019) shows that an inquiry-based approach on SSIs can foster students' critical thinking to a certain extent. Specifically, it guides students to make inquiries into SSIs, discuss these issues from interdisciplinary points of view, and use substantiated arguments. A possible way of introducing those complex SSIs is by presenting them in a narrative way using future scenarios (Boerwinkel, Swierstra & Waarlo, 2012; Knippels & Van Harskamp, 2018). As described by Boerwinkel, Swierstra, and Waarlo (2012, p. 501), future scenarios are "thought-provoking short stories describing possible futures . . . in our society and our lives". The content of these narratives should be based on recent developments in the discipline concerned, but should not be understood as a prediction of the future (Boerwinkel, et al., 2012). A characterization of these scenarios is that they stimulate the readers' imagination and present different points of view, ideas and values on what impact an issue could have in the future. Additionally, future thinking can be included by using future scenarios to explore sustainability-related SSIs. De Ruijter (2013) shows that techno-moral vignettes, which are a type of future scenarios concerned with the impact of technology on our lives, stimulate students to ask questions and clarify values and types of reasoning. This makes them suitable tools for classroom practice, for they have the educational potential to introduce Synthetic-Biology-related SSIs specifically.

This study focusses on how to approach complex, open-ended issues, that are remote from students' imagination and have a future character. Then, in a way that they will not reject or dismiss thinking about these issues but will be engaged in questioning and opinion-forming about sustainability-related SSIs. To adequately prepare students for well-informed decision making, complex and abstract sustainability-related SSIs in education demand novel approaches in understanding, managing, and stimulating engagement of our citizens. The aim of this study is to investigate the potential of future scenarios to introduce sustainability-related SSIs in science education, by designing future scenarios and evaluating them on their potential to stimulate and engage lower secondary high school science students in decision-making and opinion-forming about sustainability-related SSIs.

Theoretical framework

Scientific literacy, citizenship education and socio-scientific issues

Scientific literacy is recognized as an important aim in science education internationally (DeBoer, 2000; Sadler, 2004b). In this research, the National Science Education Standards definition is used to define a scientifically literate person as someone who is able to "use appropriate scientific processes and principles in making personal decisions" and "engage intelligently in public discourse and debate about matters of scientific and technological concern" (National Research Council, 1996, p. 13). In the Dutch education

system, the goal of scientific literacy is included in the national examination programs. One of the ways this is being realised, is through the incorporation of reasoning and making connections. This is integrated in the subject chemistry (subdomain A14 exam program chemistry) by reasoning in terms of sustainability, and in the subject geography (subdomain C1, 5c exam program geography) and biology (subdomain A12 exam program biology) by making connections between changes in the field and the consequences on society or the ecosystem. The Dutch national examination programs also focus on sustainability by paying attention to systems thinking, important for both the biology exam program and in learning for sustainable development. Geography focusses on sustainability by dealing with a global environmental issue (subdomain C2 exam program geography) (College voor Toetsen en Examens, 2018a). Furthermore, incorporation of the goal of scientific literacy in the national examination programs is being realised through the inclusion of “valuing and judging” (subdomain A9 exam program biology, physics, and chemistry) (College voor Toetsen en Examens, 2018b, 2018c, 2018d). In addition, this goal is emphasized by promoting active citizenship within Dutch policy documents such as: “*Onsonderwijs2032*” (2016). This is in line with the rationale of the Dutch curriculum that is preparing students for citizenship. The Dutch curriculum prepares students for citizenship by, among other things, providing enough knowledge to participate in discussions and form an opinion about scientific issues that need societal input (Boerwinkel, Veugelers, Waarlo, 2009). Furthermore, students are prepared by providing skills to engage in dialogue and to cooperate, take responsibility for own actions and relationships with others, deal with a variety of interests and points of view, and to resolve conflicts by respecting others (Stichting Leerplanontwikkeling, 2006; Bureau Platform Onderwijs2032, 2016). This goal of education is defined as citizenship education. Dutch schools are accordingly obliged to address citizenship education by integrating it in different subjects, while they are left free in the way they implement it (Stichting Leerplanontwikkeling, 2006). Citizenship can be seen as a component of scientific literacy, as it focuses on acquiring insight into different scientific disciplines and being involved with and having a critical attitude towards science and society in such a way that the student can use them in valid opinion-forming and decision-making as a thoughtful citizen (Boerwinkel et al. 2009).

Scientific literacy involves a social and personal element. This is indicated by the aspects of being able to take a position in societal issues that need public input and being aware and respect others’ points of view (Sadler, 2004b). Complex, scientific issues that demand societal and personal input are defined as socio-scientific issues (SSIs) (Sadler, 2004b). SSIs are controversial, real-world problems that are informed by science, and often include an ethical component as they are socially and personally related (Sadler, Barab, and Scott, 2007). SSIs are open-ended, meaning they have no clear-cut answers. Negotiating such issues require engagement with the multidisciplinary stakeholders involved and identifying values and moral reasoning because they involve opinion-forming on a personal and/or social level (Gray & Bryce, 2006). Emotional aspects play an important role in identifying values and beliefs required for moral decision-making about SSIs (Sadler & Zeidler, 2005; Van der Zande, 2011). Emotions have been found to promote students’ ability to engage in SSIs and to assist in taking various perspectives in the process of decision-making about these issues (Sadler & Zeidler, 2004; Sadler & Zeidler, 2005; Slegers, 2014). Students’ emotions in

negotiating SSIs are therefore an important indication of underlying values and moral decision-making about these issues. Besides the important role of emotions and reasoning, asking questions supports engagement in SSIs. Questions serve as a starting point and a motive for further personal, societal and scientific investigation into possible answers and solutions for complex problems in SSIs (Knippels & Van Harskamp, 2018). Desirable, normative questions point out that the controversial character of SSIs is clearly introduced when dealing with the issue. Factual questions, focused on content knowledge about the SSI, suggest the intention of students to gather more information about the specific issue (De Ruijter, 2013). Understanding of knowledge and awareness of a knowledge gap support the process of reasoning when negotiating SSIs. Since many current scientific problems involve sustainability-related SSIs, SSI-based education could be a good way to foster scientific literacy (Sadler, 2004b; Zeidler et al., 2005; Zeidler, 2015; Bencze et al., 2020). Nowadays, students need to develop skills that are needed for refined reasoning when approaching these complex sustainability-related SSIs (Roberts & Bybee, 2014). Engaging students in opinion-forming and decision-making about such SSIs in education stimulates and engages students in negotiating these issues. In this way, we can generate a scientifically literate society that is able to cope with complex issues and make meaningful decisions for a sustainable future.

Sustainability education and future thinking

Sustainability has been defined in many different ways. In this study, the widely accepted definition by Brundtland is used, which describes sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Sustainable development involves not only the protection of the environment but also to other aspects including well-being of people and economic development. This three-sided concept is represented by the three dimensions of sustainability defined as *People*, *Planet*, and *Prosperity*. The dimension *People* refers to the intent to meet human needs, both on individual and societal level, and to the equitable and sustainable management of natural resources for the benefit of all humanity. *Planet* involves the need to preserve the planet and prevent resource depletion. The third dimension *Prosperity* focusses on economic performance, production, and consumption and includes meeting individual, financial needs (Benninghaus, Kremer, & Sprenger, 2018). In this study, these three dimensions are considered equally in the context of education and should be in balance to be able to achieve sustainable development (Riess & Mischo, 2010; Purvis, Mao, & Robinson, 2019) (see Figure 1).

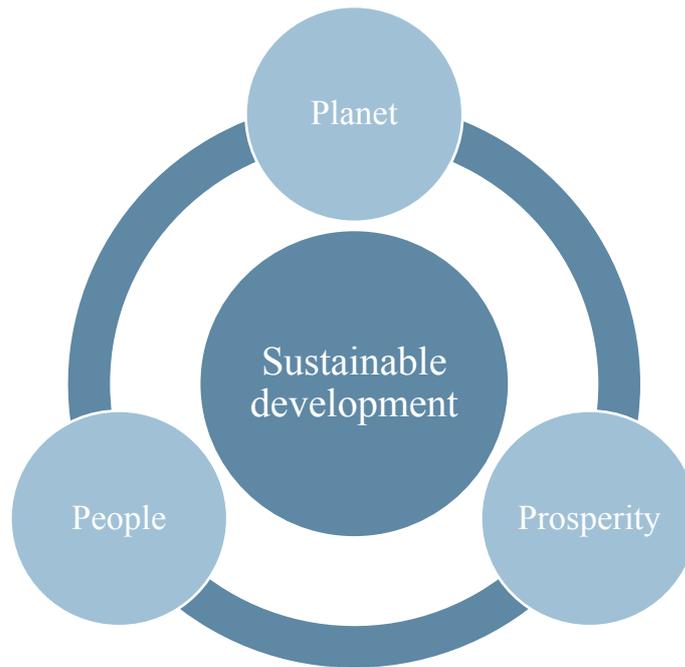


Figure 1 The three-sided concept of sustainable development referred to as People, Planet, and Prosperity. In this study, these three dimensions are considered equally in education and should be in balance in order to achieve sustainable development (Riess & Mischo, 2010; Benninghaus et al., 2018).

The current global environmental crisis with an increasing population and a deficiency of resources involves a broad range of SSIs that are expected to negatively affect the sustainable future (Gutierrez, 2015). Now, more than ever, education should enable students to acquire relevant knowledge, skills, and values to be able to commit to a sustainable future in the 21st century. The Dutch national examination programs focus on sustainability among other things by reasoning in terms of sustainability and by dealing with a global environmental issue (College voor Toetsen en Examens, 2018a, 2018b, 2018c, 2018d).

Students acquire relevant scientific, societal, and personal knowledge by clarifying values, forming an opinion and making a well-informed decision as a thoughtful citizen (Sadler, 2002; Waarlo, 2014). Both citizenship and the view on sustainability as described above require a focus on the future, so based on imagination. This future thinking includes a structured exploration into how society and its physical and cultural environment could be shaped in the future in a sustainable way (Jones et al., 2012). Wiek, Withycombe, and Redman (2011) describe five main competences in sustainability education that could serve as a guideline to adequately integrate sustainable development in education. These include systems-thinking, and normative, strategic, interpersonal, and anticipatory competence. The latter is described as “the ability to collectively analyse, evaluate, and craft rich “pictures” of the future related to sustainability issues and sustainability problem solving frameworks” (Wiek et al., 2011, p. 207). The name ‘pictures’ in this context represents an open concept to include, among other things, narratives and imagery (Wiek et al., 2011). The researchers

suggest that the competence of sustainability thinking on future impacts in a problem-solving context is one of the most important aspects in sustainability education.

Future thinking is described by Amara (1981) as “detecting, inventing, analysing and evaluating possible, probable and preferable futures”, thus describing a range of possible future scenarios, predictions, and options of choices and alternatives. Implementing future thinking in sustainability education can stimulate students’ engagement, communication of values, and enhance critical thinking skills (Jones et al., 2012). Furthermore, Lloyd and Wallace (2004) describe the myth of technology and science being neutral, free of values and objective, and that with technical expertise every problem could be solved. Future thinking has the ability to provide a more complete and realistic view of the impact of science and technology. In addition, implementing future thinking in formal education provides opportunities for students to develop analysis and argumentation skills. These key competencies are recognised by the OECD project Definition and Selection of Competencies (DeSeCo) as being important for people to be able to contribute meaningfully to a well-informed society (Rychen & Salganik, 2003). Therefore, future thinking can provide opportunities when incorporated in SSI-focused science education, by building possible, probable, and preferable future scenarios for students to reflect on their own as well as others’ values.

Knippels and Van Harskamp (2018) describe an educational sequence to support students’ future thinking in the context of SSIs, by implementing Socio-Scientific Inquiry-Based Learning (SSIBL) (Levinson, 2018). Students’ “need to know” can be developed by exploring possible and probable future scenarios, which can be explored in a classroom setting using an inquiry approach. Effective SSI-based education requires an adequate introduction of a dilemma, to generate students’ interest and engagement (Waarlo, 2014; Knippels & Van Harskamp, 2018). However, introducing sustainability-related SSIs in the classroom is challenging because they often involve complex science knowledge and abstract long-term impacts that are hard to comprehend (Jones et al., 2012). This challenge is compounded by absence of societal and ethical aspects of science in current continuing professional development courses for pre-service science teachers. Also, teachers face problems with including controversial SSIs in the curriculum due to constraints of examination requirements and a lack of time available for including the approach of SSIs in the course content (Knippels & Van Harskamp, 2018). Additionally, there is uncertainty among teachers about a suitable approach to deal with such issues in science education (Gray & Bryce, 2006). Therefore, SSI-based education demands an adequate approach for science teachers to introduce these complex issues (Waarlo, 2014).

Using future scenarios to introduce sustainability-related SSIs in the classroom

A possible way of introducing sustainability-related SSIs is presenting them in a narrative way using future scenarios. These scenarios describe a possible future situation and could be for example short videos or texts. By presenting them in a narrative way, the complex content and future character can be connected to students’ daily life, evoking students’ questions, engagement and motivation on deeper thinking about sustainability-related SSIs (Lloyd & Wallace, 2004; Boerwinkel et al., 2012; Knippels & Van Harskamp,

2018). The use of future scenarios as realistic contexts to explore sustainability-related SSIs can offer an opportunity for including future thinking. They can help students in identifying different stakeholders and perspectives on SSIs, important for well-informed decision-making as a responsible citizen (Boerwinkel et al., 2012). Future scenarios can establish broader citizens' participation by emphasizing the practical utility of scientific knowledge and connecting this with personal and social aspects (Hodson, 2003) by presenting the issue in a tangible narrative in sustainability education.

Promising previous research shows an educational potential of future scenarios for introducing SSIs in science education. Science fiction has been successfully used before in education to provoke opinion-forming about future developments and engage in SSIs (Knippels et al. 2009; Smith, Shen, & Jiang, 2019). Also, other narratives have proven to be effective in engaging students in opinion-forming about SSIs, such as YouTube videos used by Boerwinkel, Knippels, and Waarlo (2011) to introduce a dilemma about genetic testing. De Ruijter (2013) explored the educational potential of future scenarios about future impacts of technology, so called techno-moral vignettes, for introducing SSIs related to synthetic biology. The results show the educational potential of these scenarios, because they trigger reactions such as emotions and a broad range of questions, values and reasoning types from students. These are important to develop essential knowledge needed to negotiate SSIs. This is supported by Slegers (2014) and Ripken (2015), implicating that SSI-based science education can contribute to scientific literacy. These studies show that learning and teaching activities related to techno-moral vignettes are a promising way to introduce SSIs in lessons about synthetic biology. Future scenarios can introduce the first stages (introduction of the dilemma, initial opinion-forming, and raise questions) in the educational sequence for acting out SSIBL (Knippels & van Harskamp, 2018). This can engage and stimulate students to think about SSIs on a deeper level and evoke questions about the issue (De Ruijter, 2013).

In summary, future scenarios seem fruitful in engaging students in the opinion-forming and decision-making process about SSIs. This promotes students' engagement and motivation on negotiating these issues. Sustainability-related SSIs often involve complex science knowledge and ask for imagination of abstract future implications that are hard to comprehend. The narrative character of future scenarios can connect the complex content and future character of sustainability-related SSIs to students' daily life, stimulate students' imagination and present different points of view, ideas, and values on what impact issues can have in the future.

This study aims to design future scenarios and explore their educational potential, to foster students' opinion-forming about sustainability-related SSIs. This research focusses on lower secondary school students specifically because these students did not yet choose a specific subject combination, as is the case in upper-secondary school. This is important because the goal of citizenship education applies to every student, regardless of their study path, because all should ultimately be competent to engage with science related issues as a thoughtful citizen. The educational potential of the future scenarios will be evaluated based on the important role of clarifying and communicating values for opinion-forming, and decision-making in citizenship education, and the significant role of emotions, moral reasoning, and raising questions in negotiating SSIs. Moreover, students' remarks to the three dimensions *People*, *Planet*, and *Prosperity* are of importance in the evaluation of the future

scenarios because of their prominent role in sustainability education. To our knowledge no future scenarios are designed yet for secondary education to introduce sustainability-related SSIs specifically. As implicated by previous research, the content of future scenarios should be selected carefully (Boerwinkel et al., 2012). Boerwinkel et al. (2012) defined guidelines for designing and implementing future scenarios (see Table 1) and in the specific context of sustainability, Lloyd & Wallace (2004) describe stimulating future thinking as an important aspect in SSI-based education. Table 1 shows characterizations derived from literature that are used as a guideline in the design of the future scenarios (criteria 1-3) and in the evaluation of their educational potential to introduce sustainability-related SSIs in science education (criteria 4-6) (Lloyd & Wallace, 2004; Boerwinkel et al., 2012).

Table 1 Criteria derived from literature, for an adequate design and implementation of future scenarios with educational potential for introducing sustainability-related SSIs in science education (Lloyd & Wallace, 2004¹; Boerwinkel et al., 2012²)

1.	They incorporate a complex SSI that is not too far in the future, that is open-ended and has no clear-cut solution. ²
2.	They provide a concrete and realistic view of the impact of science and technology that includes changes in what is regarded normal and provoke societal debate. ²
3.	They present involved stakeholders that react in a realistic way, comparable to similar previous situations. ²
4.	They raise awareness on the complexity and interdisciplinary character of SSIs by connecting scientific, societal, and personal knowledge and values. ^{1,2}
5.	They stimulate future thinking about sustainability on a deeper level and stimulate students to ask questions. ¹
6.	They support students in their opinion-forming process based on scientific sources and guide them in well-informed decision-making, by encouraging students to explore their values beyond their initial thoughts and emotions. ²

Research question

This study explores the design and educational potential of future scenarios for introducing sustainability-related SSIs in science education, and addresses the following main question: What is the educational potential of future scenarios for introducing sustainability-related SSIs in lower secondary science education?

The following sub-questions are formulated:

1. What kind of questions and emotions can future scenarios evoke in Dutch lower secondary school students?
2. What kind of underlying values and moral reasoning can future scenarios evoke in Dutch lower secondary school students?

Method

In this section, the design of the future scenarios as an instrument, the selection of the participants for this study and the collection and analysis of the data is described.

Design of the future scenarios

In designing the sustainability-related future scenarios, the guidelines of Boerwinkel et al. (2012) (Table 1) were used as a starting point. These criteria were refined based on a review of recent scientific literature on opinion-forming, decision-making and future thinking in sustainability-related SSI-based education. As a result of this literature study, the described criteria in table 1 were refined. A few minor adjustments were made with regard to clarifying and extension of the description of the criteria in table 1. Based on the refined design criteria, six future scenarios were developed (Table 2, criteria 1-3; Appendix 1-6). The topic of each future scenario was selected carefully in order to describe a current sustainability issue that is relevant to the present time and therefore relevant to students' daily life, such as biodiversity, food supply, and the fashion industry (Gutierrez, 2015). To increase the validity of the design these six future scenarios were discussed with both supervisors. Also, the scenarios were discussed with a Science Communication Expert of the Freudenthal Institute, Utrecht University to refine the narratives.

EDUCATIONAL POTENTIAL OF FUTURE SCENARIOS

Table 2 Description of criteria derived from literature (Table 1) and their application in the design and evaluation of six future scenarios. Criteria 1-3 are used as guidelines in the design of the future scenarios. Criteria 4-6 are used as guidelines in the evaluation of their educational potential to introduce sustainability-related SSIs in science education and are therefore justified after the evaluation (gray cells).

		Future scenario					
		The Netherlands under water (Nederland onder water)	Blue Energy (Blauwe Energie)	Future food (Eten in de toekomst)	Bye bye fashion! (Bye bye mode!)	The future supermarket (Boodschappen doen in de toekomst)	Biodiversity (Biodiversiteit)
	Topic	Water management	Energy policy	Food supply	Fashion industry	Food production	Biodiversity
Design criteria	1. They incorporate a complex SSI that is not too far in the future, that is open-ended and has no clear-cut solution.	Is flooding of The Netherlands inevitable?	Which strategy is best to generate energy in a sustainable way?	Should we have controlled food consumption, in favor of a more equal food distribution?	What is the best strategy to make the fashion industry more sustainable?	What is the best strategy to make the food production process more sustainable?	Which strategy is best to ensure the conservation of biodiversity?
	2. They provide a concrete and realistic view of the impact of science and technology that includes	Human polluting behavior, like resource	A more sustainable strategy to generate	A controlled food production and	A more sustainable fashion industry can	A more sustainable food production	More governmental control and less autonomy

	changes in what is regarded normal and provoke societal debate.	depletion, can contribute to climate change with flooding as a possible consequence.	energy, via blue power plants, can cause inequity and may affect living environments of marine animals.	distribution may maintain overpopulation and decrease human autonomy.	decrease human autonomy and make original cities and “fashion” disappear.	may involve cultured meet and limit free will as a result of governmental control.	may help preserve biodiversity-loss caused by human actions.
	3. They present involved stakeholders that react in a realistic way, comparable to similar previous situations.	Stakeholders: Authorities in resource extraction and waste disposal, Dutch and German citizens, tourists, farmers, animals.	Stakeholders: authorities in the field of water experts, Dutch citizens, citizens from water-poor countries, ship traffic, fisherman, marine animals.	Stakeholders: citizens from both under-privileged countries and “self-sufficient cities”, the government.	Stakeholders: present and former citizens, fashion designers, factory workers, employees of the new fashion network.	Stakeholders: citizens, supermarkets, meet industry, animals.	Stakeholders: Dutch citizens, animals, the government, provinces, municipalities, European countries.
Evaluation criteria	4. They raise awareness on the complexity and interdisciplinary character of SSIs by connecting						

	<p>scientific, societal, and personal knowledge and values.</p>						
	<p>5. They stimulate future thinking about sustainability on a deeper level and stimulate students to ask questions.</p>						
	<p>6. They support students in their opinion-forming process based on scientific sources and guide them in well-informed decision-making, by encouraging students to explore their values beyond their initial thoughts and emotions.</p>						

EDUCATIONAL POTENTIAL OF FUTURE SCENARIOS

Pilot test

The developed six future scenarios were pilot tested with three students (3 females, two future scenarios per student) in a semi-structured interview. Student levels varying from pre-secondary vocational education to pre-university and with an average age of 12.3 years old. The pilot interviews aimed to explore the students' reactions to the scenarios, the connection of the scenarios to students' daily life, their comprehensibility, readability, and the time it took for the students to read them. In this pilot test, the students were asked to read the scenario and think out loud while answering questions posed by the interviewer (Appendix 7). These pilot interviews served as an opportunity to optimise the interview scheme and refine the design. Due to the current pandemic, the pilot interviews took place online via Microsoft Teams (version 1.3.00.33671). A few minor adjustments were made concerning the content and layout of the future scenarios based on these pilot interviews. Some parts of the scenarios have been removed because they appeared to be distracting from keeping the focus of the scenario on the actual dilemma and keeping the emphasis on generating discussion about the dilemma. For example, the sentence "The future looks bright for us as 'a land of water'" has been removed from the scenario 'The Netherlands under water' to keep the focus on the important sentences before and after it, so that the emphasis will be more on the inequality between countries. Furthermore, confusing words were removed or replaced by their Dutch translation, such as "reminder" in the scenario 'Blue energy', and some clarification was added to explain unclear information in the text. The pilot test resulted in six refined future scenarios (Appendix 1-6) and an optimised interview scheme (Appendix 7).

Participants

To evaluate the educational potential of future scenarios to introduce a sustainability-related SSI, 12 Dutch lower secondary school students (5 females and 7 males, second grade of high school, average age 12.5) were interviewed individually and 12 Dutch lower secondary school students (6 females and 6 males, first grade of high school, average age 12) were interviewed in a focus group setting (Table 3). Students voluntarily participated and were selected based on their availability and whether they had consent of a parent or guardian, which has been collected prior to the interviews for every participating student to engage in the study. The participants were derived from two different Dutch schools, six students from Revis Lyceum in Doorn and six from St. Bonifatiuscollege in Utrecht. Eleven students (student 1 and student 3-13) follow pre-university level education and one student (student 2) follows pre-secondary vocational education level.

Table 3 Overview of female (FS) and male (MS) students, varying from pre-secondary vocational (B) to pre-university (V) level participating in the main data collection.

Future Scenario	Individual face-to-face interview	Focus group interview
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The Netherlands under water	FSV-1, MSV-9.	MSV-21, MSV-22, FSV-23 FSV-24.
Blue Energy	MSB-2, FSV-11.	FSV-17, FSV-18, MSV-19, MVS-20.
Future food	MSV-3, FSV-12.	FSV-17, FSV-18, MSV-19, MSV-20.
Bye bye fashion!	MSV-4, FSV-10.	MSV-21, MSV-22, FSV-23 FSV-24.
The future supermarket	MSV-5, MSV-8.	FSV-13, FSV-14, MSV-15 MSV-16.
Biodiversity	FSV-6, MSV-7.	FSV-13, FSV-14, MSV-15, MSV-16.

Data sources

Data to answer both sub-questions was gathered using individual semi-structured face-to-face interviews with 13 students and three focus group interviews with four students, discussing two future scenarios each (see Table 3). The semi-structured interview scheme is available in Appendix 7. Both individual face-to-face interviews and focus groups were chosen because these methods are appropriate for gathering in-depth information on people's opinions, reasoning, and emotions (Denscombe, 2010). The individual interviews and the focus groups were conducted by the author of this paper and took place in a classroom in students' their own school. Individual face-to-face interviews were conducted to identify whether questions, emotions, values, and moral reasoning were evoked by reading the future scenarios and lasted 10 to 15 minutes. The focus group interviews that followed aimed to explore any possible effect of evoking a discussion among the students after reading the future scenarios. The focus groups took approximately 30 minutes each and were conducted in heterogeneous groups to simulate a possible real-life classroom setting where the future scenarios can be discussed in a small group setting. The interviewer served as a facilitator by only asking questions to get the discussion started and keep it going.

Data analysis

Both the face-to-face interviews and the focus groups were audio- and video-recorded to be able to analyse notable body language and distinguish different speakers during the focus group conversation. Furthermore, the interviews were transcribed verbatim, including pauses and non-grammatical sounds like *uhm*, *uh* and *[laughs]*. One individual face-to-face interview was not recorded due to technical failure. Therefore, an extra student (MVS-8; Table 3) was interviewed and included instead in the data analysis. Noteworthy remarks and insights based on the interview were written down immediately afterwards and taken in mind

when evaluating the future scenario. The transcripts of the individual face-to-face and focus group interviews were analysed based on four aspects (also see Appendix 8):

Questions

Students' questions were distinguished from the transcripts. Questions in this case are understood to entail both explicitly stated questions and implicit questions such as remarks starting with "I wonder ..." or "I would like to know ...". The following selection of questions was used to categorise the questions in four main categories:

1. Future scenario content;
2. Specific SSI-related knowledge related to the future scenario;
3. General sustainability knowledge not related to the specific scenario;
4. Desirability.

The first three categories refer to content related questions, the fourth category to normative questions.

Emotions

Students' quotes that indicate emotions were filtered from the transcripts and evaluated by the author, using a list of twelve emotions based on Evans (2002) including among others joy, anger, fear, and surprise (see Appendix 8).

Reasoning

Students' reasoning types were categorised in three categories and determined as one coding unit when one type of reasoning was used and only one subject was covered. The coding units were categorised into three main categories based on Sadler & Zeidler (2005):

1. Rationalistic reasoning: reasoning with reason-based considerations. Can be either hypothetical or under assumption, but still logically reasoned, or empirical using proven facts.
2. Emotive reasoning: reasoning with care-based considerations like empathy, directed at others.
3. Intuitive reasoning: reasoning with considerations based on immediate reactions, without conscious awareness of having gone through steps of search or weighing evidence.

Values

Students' values were categorised based on Evans (2002). These categories describe the following ethical values:

1. Autonomy: respect for free will/self-determination, respect for privacy.
2. Beneficence: doing good, promoting the well-being of others.
3. Harmless: avoid harm, do not harm others/other animals.
4. Justice: fair sharing of benefits and burdens (equality).
5. Care for nature: preserve the planet, reinforce environmental resources.
6. Responsibility: we share moral obligations to both others and to broader moral standards, we are all entitled to the same and should take our responsibility.

Three dimensions of sustainability

Students' references to the three dimensions of sustainability (*People, Planet, and Prosperity*) were used to provide valuable information about the educational potential of the future scenarios in sustainability education. The categories are described as follows (Benninghaus et al., 2018; OECD, 2019):

1. **People:** refers to meeting human needs (equal opportunities, child survival, education, belief that people can make a difference). Meeting equitable and sustainable management of natural resources for the benefit of all humanity (institutions, social capital, provinces/regions, reducing hunger and poverty).
2. **Planet:** refers to the need to preserve the planet (shared, human responsibility and respect for nature) and the use of resources in a way they will not be depleted.
3. **Prosperity:** refers to economic performance, profit, and the production and consumption of welfare. Includes productive sectors and meeting any individual needs in financial context.

All transcripts were analysed based on open coding and 578 out of 602 coding-units were coded by an independent second researcher to ensure reliability. Because of the many different coding categories, the agreement between the first and second coder was determined by percentage of agreement calculations. Final agreement was calculated as 93.62% for the questions, 92.71% for the emotions, and 91.18% for the types of reasoning found in the transcripts. With all categories taken together, the overall percentage of agreement between the first and second coder was 94.38%.

Usability to provoke discussion in classroom setting

In the individual face-to-face interviews, students were asked to value the future scenario they read, based on the possibility to provoke a discussion in a classroom setting and substantiate why they think so. According to the students' answers, the future scenarios were coded with 'yes' or 'no', indicating whether they think the future scenarios are useful to provoke a discussion or not. The reasons given by the students as a support of their answer were used to provide additional information about the possible educational potential of the scenarios.

COVID-19

Due to restrictive measures because of the COVID-19 pandemic, the pilot interviews could not be conducted in real life but instead took place online via Microsoft Teams (version 1.3.00.33671). This did not have further impact on the method of this research.

Results

The educational potential of future scenarios for introducing sustainability-related SSIs in science education was explored by answering the two sub-research. Because of the qualitative character of this study the data is described in a descriptive way. Quotations are

used to clarify findings and are provided with a code that gives information about the interview setting and the gender of the student in question (see also Table 3). The first letter of the code refers to the interview setting, where “I” indicates individual face-to-face interviews and “G” indicates focus group interviews. Furthermore, “Int.” refers to comments by the interviewer.

Sub-question 1: What kind of questions and emotions can Future Scenarios evoke in Dutch lower secondary school students?

Questions

All future scenarios evoked questions in students, with an overall total of 114 questions of which 43 in the focus group interviews 71 in the individual face-to-face interviews (see Table 4). The questions raised in students were sorted by type into several categories, including content-related questions, questions about knowledge related to the specific SSI in the scenario, general knowledge questions, and desirable questions (Table 4; Appendix 8).

Overall, most questions were content-related and specifically focused on the future situation in the scenarios and what that would be like, with ‘Future food’ raising the most of this type of question compared to the other scenarios. The following quote gives an example of such a question evoked by the scenario ‘Future food’:

Int.: *And do you have any more questions that come to mind?*

I-FSV-12: *Hm... Yes, if there is such an uhm yes, such a phase in life sort of [as described in the scenario], would you then [in that future situation] still be able to buy things that are tasty?*

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Table 4 Number and types of students' questions raised by the future scenarios, in individual face-to-face interviews shown in the light blue cells and in focus group interviews shown in the dark blue cells. Categories, a description of the categories, and examples of quotes from the student interviews are given.

Category	Description	Example	The Netherlands under water		Blue Energy		Future food		Bye bye fashion!		The future supermarket		Biodiversity		Total
			0	0	0	7	0	9	1	0	0	2	1	3	
Content	About the scenario specific content (the story itself). Not about the process behind the future situation that is described.	<i>“Why are there pills on it [the image in the scenario]?”</i> <i>“And (...) it said ‘recreation’ uh ‘recreational’ and ‘climate adaptive’ and I don’t really understand what that means.”</i>	0	0	0	7	0	9	1	0	0	2	1	3	23
	About the future situation in the scenario and how that would be.	<i>“By then [in the future situation] would there really for example be a pill that prevents you from getting fat?”</i>	1	3	1	7	6	7	1	3	2	3	3	2	39
Knowledge	About the functioning of a process/mechanism: how does this work?	<i>“Would it be possible to use the plastic soup instead of textile for the 3D printer?”</i>	4	0	0	6	0	2	2	2	3	1	5	0	25

	About the state of the development in this field: how is this now and how could something like this happen in the future?	<i>“Yes... That is already possible, isn’t it?”.</i>	2	0	0	4	1	3	0	0	2	1	1	0	14
General knowledge	About general knowledge (about sustainability), not related to the specific scenario.	<i>“The government is just... is just actually the state, right?”</i>	0	0	0	2	0	1	0	0	0	2	0	1	6
Desirability	About what is good or what should be allowed: is this wat we want?	<i>“And how do you feel about that? Well... no sadness but it is like, why don’t we do better?”</i>	1	0	1	0	2	0	2	0	0	0	1	0	7

	Number of questions individual interview 1	5	0	2	4	5	8	24
	Number of questions individual interview 2	3	2	7	2	2	3	19
	Number of questions focus group	3	26	22	5	9	6	71
	Absolute total	11	28	31	11	16	17	114
	Relative total (%)	9.7	24.6	27.2	9.7	14.0	14.9	

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The future scenarios overall evoked relatively few general-knowledge (6 questions) and questions about desirability (7 questions), of which no desirability questions at all were raised in the focus group interviews. The highest total number of questions was raised in the future scenarios 'Blue energy' (28 questions) and 'Future food' (31 questions) of which the vast majority of questions was raised in the focus group interviews (26/28 for 'Blue energy' and 22/31 for 'Future food'). 'Blue energy' mostly evoked content-related questions and knowledge questions about the functioning of specific processes in the scenario. The following quote demonstrates the difference between two types of knowledge-questions about 'Blue energy', about the mechanism of generating energy by using water and its influence on boat rides and about the state of the development in this field:

G-FSV-18: *Yes, and here [in the future scenario] they do, they use water to generate energy.*

G-FSV-17: *Yes... That is already possible, isn't it?*

G-MSV-19: *Yes, with an uh uhm a water wheel, but uhm then boats can also sail on it. Then there are even more waves and then it goes even... then it produces more energy.*

G-FSV-17: *But I do not understand how... how they then... I also want to know how they do that and why then boats cannot sail?*

The fewest questions were raised by the future scenarios 'The Netherlands under water' and 'Bye bye fashion!', which in total evoked both 11 questions each of which mainly were raised in the individual face-to-face interviews. The scenario 'The Netherlands under water' raised no content-related questions about the story itself and the scenario 'Bye bye fashion!' only one. For example, such a question is represented in a student interview about 'Bye bye fashion!':

Int.: *Okay. And uhm are there any other things you would like to say about the text? Questions or comments, or anything of which you thought well this uh... it can be anything that comes to mind.*

I-FSV-10: *Uhm yes, why does that person [in the scenario] go by scooter? He can go by bike. Going by scooter is not sustainable.*

Int.: *Hm hm.*

I-FSV-10: *So, and then you go and buy clothes from a 3D printer, but then you still go to school by scooter.*

Int.: *Yes [laughs].*

I-FSV-10: *That does not seem right to me.*

Emotions

All future scenarios evoked emotions in students, with an overall total of 178 emotions of which more in the individual face-to-face interviews (94 emotions) than in the focus group interviews (84 emotions) (see Table 5). The emotions raised in students were categorised into several categories, including among others joy, anger, confusion, and sadness (Table 5; Appendix 8).

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Table 5 Number and types of students' emotions raised by the future scenarios, in individual face-to-face interviews shown in the light blue cells and in focus group interviews shown in the dark blue cells. Categories, a description of the categories, and examples of quotes from the student interviews are given.

Category	Description	Example	The Netherlands under water		Blue energy		Future food		Bye bye fashion!		The future supermarket		Biodiversity		Total
			0	0	0	3	1	1	2	0	2	1	1	0	
Joy	Joy, gladness, feeling of joy, amused, optimistic, gratitude.	<i>“Well, it is kind of funny, things about the future that might happen, I find it funny.”</i>	0	0	0	3	1	1	2	0	2	1	1	0	11
Optimism	Optimism, satisfaction, contentment, positive, pleased.	<i>“It seems good for the animals and the environment. That seems to me that it has improved.”</i>	0	3	5	2	0	2	2	1	6	5	5	3	34
Anger	Anger, irritability, annoyance, frustration, rage, envy.	<i>“Because there also have to live other people after their own lives, but yeah, they are just selfish.”</i>	0	0	0	0	0	0	1	0	0	0	2	0	3
Fear	Fear, feeling of oppression, fear, insecurity, bad,	<i>“Well, scary. I don't know when this could happen then.”</i>	2	1	0	0	0	2	0	2	2	1	3	4	17

	frightened, shocked, worry, anxiety.	<i>But if this happens soon in the future, that seems scary to me.</i>													
Surprised	Surprise, astonishment, amazement, state of mind when perceiving something unexpected, wonder.	<i>“On the contrary, I would think that there will be less greenery later on because there will be even more people and that is not the case here.”</i>	0	0	0	2	0	0	0	0	0	0	0	1	3
Curiosity	Disgust, aversion, nausea. Contempt, often towards an individual, group or ideology.	<i>“But I think that would be interesting to know.”</i>	0	0	2	0	1	0	1	0	1	0	0	0	5
Disgust	Curiosity, interested, intrigued (when the student indicates that they want to know more but not coded when interest is shown only by asking a question).	<i>“Just [...] selfish. That we only want everything for ourselves.”</i>	0	0	0	0	0	2	1	0	0	0	3	0	6
Confusion	Confusion, strange, weird, hard to imagine. In reaction to the future situation described, to the content of the scenario.	<i>“Uhm, that would be really weird. Just no more fish [laughs].”</i>	3	1	2	3	8	9	1	2	3	5	4	0	41

Entanglement	Entangled, vague, confounded. In reaction to unclear information, text, image.	<i>“Only uh it was sometimes a bit uh difficult to understand let us just say.”</i>	0	0	1	4	0	6	1	0	0	3	4	3	22
Pity	Pity, sympathy, compassion, sympathetic sorrow evoked by the suffering of others.	<i>“If you are a refugee and come to The Netherlands, then, yes it would be nice if you just have a house and are no longer sent away...”</i>	1	0	4	0	1	0	1	1	0	0	0	0	8
Sadness	Sadness, mental pain, suffer, despair, unhappiness, shame, disappointment, discontentment, uncomfortable, the feeling of dissatisfaction that follow the failure of expectations or hopes to manifest.	<i>“Well look, it might not be fun, it’s maybe just healthy or something like that, but... Yes, I would just find it a shame.”</i>	2	3	4	1	4	1	3	4	3	1	1	2	29

Number of emotions individual interview 1	4	7	5	7	7	9	39
Number of emotions individual interview 2	4	11	10	6	10	14	55
Number of emotions focus group	8	15	23	10	16	12	84
Absolute total	16	33	38	23	33	35	178
Relative total (%)	9.0	18.5	21.4	12.9	18.5	19.7	

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In total, the two scenarios that evoked the most emotions in students are 'Future food' (38 emotions) and 'Biodiversity' (35 emotions) of which the majority was raised in the focus group interview regarding 'Future food' (23/38 emotions) and in the individual face-to-face interviews regarding 'Biodiversity' (23/25 emotions). The scenario 'Future food' raised mostly confusion, entanglement, and sadness in students, such as "*Yeah I just think it is a bit weird that they suddenly say that or something*". The scenario 'Biodiversity' raised mostly a feeling of optimism, fear, and entanglement. The least emotions were raised by the future scenario 'The Netherlands under water' (16 emotions), most of which were sadness (5). The scenario 'Bye bye fashion!' raised 23 emotions in total, most of which were also sadness (7), such as "*Not everyone should start wearing leather because then it gets a bit, then it looks a bit boring. Then there are no longer differences between personalities*".

All together the emotions that were raised most by the scenarios were confusion, optimism, and sadness which were slightly more evoked in the individual face-to-face interviews compared to the focus group interviews but were all three raised by each scenario. Confusion in this study refers to the feeling of perceiving something strange or hard to imagine and was raised mostly by 'Future food' compared to the other scenarios (17/41 in total). The following quote about the scenario 'Blue energy' gives an example of confusion, because the student finds the future situation strange:

Int.: *Then I have another uh do you have a final comment or question, or anything you want to say about what you think about this?*

G-FSV-17: *I think it is weird if it turns out to be like this later.*

G-FSV-18: *Yes, me too. If it really will be like this later.*

Some students find the development described in the scenario hard to imagine and therefore feels confused, for example in a students' reaction to 'Future food':

I-MSV-3: *[...] I think it is a bit weird that the government would do something like that... I don't think... I personally would not think that the government would decide what we eat.*

Int.: *And by that you mean that you think that it is not going to get that far?*

I-MSV-3: *Yes nods.*

Overall, the scenarios 'Blue energy', 'The future supermarket', and 'Biodiversity' trigger mostly a feeling of optimism in students, whereas sadness and confusion were raised mainly in students reacting to the scenarios 'The Netherlands under water', 'Future food', and 'Bye bye fashion!'. Other feelings such as anger and surprise only appeared in reactions to some of the scenarios, including 'Bye bye fashion', 'Biodiversity', and 'Blue energy'.

Sub-question 2: What kind of underlying values and moral reasoning can Future Scenarios evoke in Dutch lower secondary school students?

Values

Analysis of all student interview transcripts revealed 105 instances of values, of which 63 in the face-to-face interviews and 42 in the focus group interviews (see Table 6). The values raised in students were categorised into several categories, including autonomy, beneficence, harmless, justice, care for nature, and responsibility (see Table 4; Appendix 8).

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Table 6 Number and types of students' questions values by the future scenarios, in individual face-to-face interviews shown in the light blue cells and in focus group interviews shown in the dark blue cells. Categories, a description of the categories, and examples of types of questions are given.

Category	Description	Example	The Netherlands under water		Blue Energy		Future food		Bye bye fashion!		The future supermarket		Biodiversity		Total
Autonomy	Respect for free will/self-determination (freedom and agency). Respect for privacy.	<i>"I think people should be able to choose what they eat and then I do not understand why it would be the government."</i>	0	0	0	0	4	6	2	2	5	1	0	1	21
Beneficence	Doing good, an act that does someone good, promote the well-being of others.	<i>"But I do think that [...] many more people [...] think of 'well then we are going to solve other crises'".</i>	2	0	1	1	2	2	0	1	1	2	0	0	12
Harmless	Do no harm, avoid harm, do not harm others/other animals.	<i>"I think that it is very useful because you have to kill animals for that, of course, not uh the nicest way to get food."</i>	0	1	2	0	1	0	2	1	2	4	0	3	16

Justice	Fair sharing of benefits and burdens, social equity. Everyone is entitled to the same. For example, equal opportunities, child survival, education, commitment to social justice and equity.	<i>“The Netherlands should actually give some energy to other countries, if we have too much.”</i>	0	3	3	0	2	2	2	0	0	0	1	2	15
Care for nature	Preserve the planet, reinforce environmental resources.	<i>“I think we should uh just keep forest growth the same, uh cut down less forest and maybe start planting more.”</i>	0	0	7	1	0	1	4	3	1	2	1	2	31
Responsibility	We share moral obligations to both others and to broader moral standards, we are all entitled to the same and should take our responsibility.	<i>“Because I just think that if we all work together, we can keep this [climate change] under control”</i>	2	0	0	0	0	0	2	0	1	0	4	1	10

Number of values individual interview 1	1	6	2	6	8	7	30
Number of values individual interview 2	3	7	7	6	2	8	33
Number of values focus group	4	2	11	7	9	9	42
Absolute total	8	15	20	19	19	24	105
Relative total (%)	7.6	14.3	19.1	18.1	18.1	22.9	

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Overall, most values were related to care for nature (31/105 in total), with the scenario 'Biodiversity' raising most of such values (12) compared to the other scenarios. This is illustrated by the following quote about the scenario 'Biodiversity':

Int.: *And what kind of negative factors [of human influence on nature], for example?*

I-FSV-7: *Well, for example in the Amazon. Yes, we are there already doing... we human do everything for nature, but everything breaks down, and... We are just losing acres.*

Int.: *Yes. And what do you think about that?*

I-FSV-7: *Well, I actually think it is really... yeah, I really do not think it is good per se because it is really our oxygen source of the world. And... Yes... I think it is just strange that people only want to instigate agriculture for life, well, instead of habitat for animals and... Yes, I think that is a bit stupid.*

Another student reacted to the scenario 'Biodiversity' by also emphasizing the importance of protecting nature:

I-FSV-6: *And uh the forest is also a whole place where people can come to re-uh calmness and if we have less forest then maybe people will get stressed more quickly which might make us all even less environmentally friendly.*

Values concerning autonomy were raised second most by the future scenarios (21/105 in total), with the scenario 'Future Food' raising most of such values (10) compared to the other scenarios and 'The Netherlands under water' and 'Blue energy' evoking none. For example, some students described values with respect to freedom of choice in their reaction to 'The future supermarket':

G-FSV-18.: *Yes, but it seems strange to me if you can no longer choose for yourself [what to eat], because that is kind of a...*

G-FSV-17: *I think, I think...*

G-FSV-18: *... is an important thing or something anyway.*

G-FSV-17: *Yes.*

And:

I-MSV-5.: *I think it is a very practical solution [sustainable food supply described in scenario], that in theory it could work well. But, as a human being you still want to have freedom of choice, make choices, and I don't think this could work fully because uhm it is all determined for you, so you didn't think... well, I would find it annoying myself.*

Int.: *Yes.*

I-MSV-5: *Because even if I would might choose the same as the supermarket would decide for me, it would be nice if I had made the choice myself or something.*

Int.: *Yes, I can imagine.*

I-MSV-5: *Then it feels like I have more influence on this or something.*

In total, the scenario 'Biodiversity' raised the most values in students. 'The Netherlands under water' evoked the least with in total eight values of which most were related to justice.

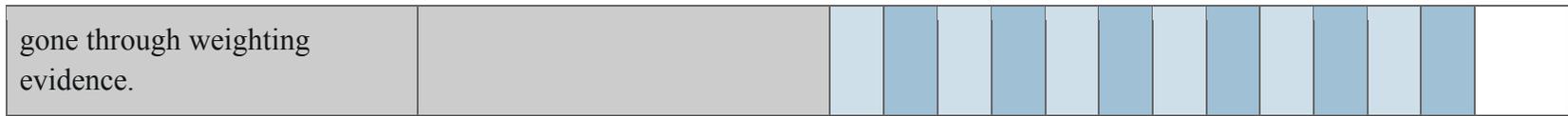
Reasoning

All future scenarios evoked various types of reasoning in students, with an overall total of 180 types of reasoning of which more in the individual face-to-face interviews (100) than in the focus group interviews (80) (see Table 7). The scenarios that most strongly stimulated students' reasoning are 'Blue energy' (34 instances of reasoning) and 'Biodiversity' (36 instances of reasoning). Reasoning evoked in students was categorised into several categories, including rationalistic, emotive, and intuitive reasoning (Table 7; Appendix 8).

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Table 7 Number and types of students' reasoning raised by the future scenarios, in individual face-to-face interviews shown in the light blue cells and in focus group interviews shown in the dark blue cells. Categories, a description of the categories, and examples of types of questions are given.

Category	Description	Example	The Netherlands under water		Blue energy		Future food		Bye bye fashion!		The future supermarket		Biodiversity		Total
			6	6	6	7	5	3	7	5	6	5	6	9	
Rationalistic	Reason-based considerations, using logic. Can be either hypothetical or under assumption, but still logically reasoned or empirical using proven facts.	<i>“France is also on the coast, so it is all flooded then.”</i>	6	6	6	7	5	3	7	5	6	5	6	9	71
Emotive	Care-based considerations like empathy, considerations directed at others.	<i>“The Netherlands should actually give some energy to other countries, if we have too much.”</i>	2	0	5	0	6	2	6	3	3	1	6	4	38
Intuitive	Considerations based on immediate reactions to the context of the scenario, without conscious awareness of having	<i>“But I think, look they are talking about the future, but I do not think this will be in five years' time...”</i>	3	7	8	8	5	9	3	4	9	4	8	3	71



Number of reasoning individual interview 1	6	8	5	10	12	10	51
Number of reasoning individual interview 2	5	11	11	6	6	10	49
Number of reasoning focus group	13	15	14	12	10	16	80
Absolute total	24	34	30	28	28	36	180
Relative total (%)	13.3	18.9	16.7	15.6	15.6	20.0	

EDUCATIONAL POTENTIAL OF FUTURE SCENARIOS

Rationalistic reasoning involves reason-based considerations, either hypothetical or empirical, whether intuitive reasoning is based on immediate reaction to the scenario and substantiated without weighing evidence. In reactions to the scenarios ‘The Netherlands under water’, ‘Bye bye fashion!’, and ‘Biodiversity’ students mostly relied on rationalistic reasoning. Intuitive reasoning was used mostly by students in reaction to the scenarios ‘Blue energy’, ‘Future food’, and ‘The future supermarket’. This is represented by a quote from a student relying on intuitive reasoning in reaction to the scenario ‘The future supermarket’:

I-MSV-5: *Because I think it is feasible in itself, but I don't know if it is, or if it uhm, it is far in the future I think. At least it feels that way a bit.*

Another example is shown from a student relying on emotive reasoning in reaction to ‘Bye bye fashion’, based on care-based considerations directed at others:

G-FSV-24: *It is actually also the case, clothing is quite important in let us say society. Because there are a lot of people who are working on it, who just work there to make clothes and there are also many clothing stores etcetera. And if that only happens online and because of everything, that is, it just seems almost impossible to me because then so many people would lose their jobs if that would happen, so...*

Overall, all scenarios were found to trigger different types of reasoning of which ‘The Netherland under water’ showed the least emotive reasoning in students’ reactions compared to the other scenarios. It is noteworthy that students often relied on a combination of different types of reasoning throughout their reaction on the future scenarios.

Three dimensions of sustainability

A categorisation of students’ references to the three dimensions of sustainability was included because of their prominent role in sustainability education. The categories included People (referring to the need to meet human needs), Planet (referring to the need to preserve the planet), and Prosperity (referring to the need to meet any individual needs in financial context) (see table 8; appendix 8).

Students remarked different dimensions of sustainability in reaction to the different future scenarios. This is indicated by a quote about ‘Bye bye fashion!’, where students refer to all three dimensions of sustainability:

G-FSV-24: *People now also say that it [electric vehicles] is more sustainable and so on, but I also think that in the end all those technical things are not that good for society and the economy and all that.*

G-FSV-23: *Yes.*

G-MSV-21: *Hm hm, but I do think it is better than...*

G-MSV-22: *Better for the world but...*

G-MSV-21: *Yes, that is right.*

G-FSV-23: *To build it is also really a lot of...*

G-FSV-24: *Yes. Then there are so many innovations that also cost a lot of ‘things’.*

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Table 8 Number and types of students' references to the three dimensions of sustainability (People, Planet, and Prosperity). Evoked by the future scenarios, in individual face-to-face interviews shown in the light blue cells and in focus group interviews shown in the dark blue cells. Categories, a description of the categories, and examples of types of questions are given.

Category	Description	Example	The Netherlands under water		Blue Energy		Future food		Bye bye fashion!		The future supermarket		Biodiversity		Total
			2	3	1	0	3	3	1	1	1	1	3	2	
People	Refers to meeting human needs. Meeting equitable and sustainable management of natural resources for the benefit of all humanity.	<i>"I think it could happen because of the overpopulation, and that they can then feed more people and fewer people will be poor."</i>	2	3	1	0	3	3	1	1	1	1	3	2	21
Planet	Refers to the need to preserve the planet (shared, human responsibility and respect for nature) and the use of resources in a way they will not be depleted.	<i>"It is just a bit boring, but if that is more sustainable and better for the world then I'm fine with it."</i>	2	1	7	2	1	1	6	3	2	2	1 3	3	43
Prosperity	Refers to economic performance, profit, and the production and consumption of welfare. Includes productive	<i>"It says no year here [in the scenario] but I think if this is pretty soon after Corona, that it</i>	0	1	0	1	0	1	2	3	0	0	0	0	8

sectors and meeting any individual needs in financial context.	<i>really uh that this then really the whole economy collapses.</i>												
--	---	--	--	--	--	--	--	--	--	--	--	--	--

Number of dimensions individual interview 1	1	4	1	5	3	7	21
Number of dimension individual interview 2	3	4	3	4	0	8	22
Number of dimensions focus group	5	3	5	7	3	5	28
Absolute total	9	11	9	16	6	20	71
Relative total (%)	12.7	15.5	12.7	22.5	8.5	28.2	

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Overall, students only made little references to *Prosperity* (8) of which not even at all in their reactions to 'The future supermarket' and 'Biodiversity'. *Planet* was remarked more than five times as much (43 references) by the students. This latter category was mainly covered by the scenarios 'Biodiversity' (16/43), 'Bye bye fashion' (9/43), and 'Blue energy' (9/43) in individual face-to-face setting. All scenarios except from 'The future supermarket' and 'Biodiversity' were found to cover all three dimensions of sustainability.

Usability to provoke discussion in classroom setting

In the individual face-to-face interviews, students were asked to decide on the usability of the future scenarios to provoke discussion in classroom setting. According to the students' answers, the future scenarios were coded with 'yes' (useful) or 'no' (not useful) (Appendix 8). All scenarios except from 'Bye bye fashion!' were considered useful for provoking discussion by at least one student. Students gave several reasons to substantiate why they think so. Those who believed that the future scenario they read was not useful for provoking discussion in classroom setting, argued that this was due to a lack of information presented ('Biodiversity'), and by only showing one perspective ('The Netherlands under water' and 'Bye bye fashion!'). Students who believed that the future scenario they read was useful for provoking discussion, argued among other things that this was due to opposing opinions ('Blue energy', 'Future food', 'The future supermarket', and 'The Netherlands under water'), a variety of topics ('Biodiversity'), and a relatable story presented by the scenario ('Blue energy'). For example, one student believed that the scenario 'Blue energy' could provoke discussion because of opposing opinions involved in the dilemma:

I-FSV-11: *Uhm I think the conversation then [in classroom setting], I think it's pretty much about the environment and so on. That it might still be bad. But on the other hand, there are also people who think that it is very good and... that it solves all problems.*

Int.: *Yes.*

I-FSV-11: *I think so.*

Int.: *So that some people would like it, but others would not like it?*

I-FSV-11: *Yes.*

While another student did not believe that the scenario 'Bye bye fashion!' could provoke discussion because of a lack of different perspectives:

I-FSV-10: *Yes, I do not think so because I think just everyone, let us say, wants to do things that are more sustainable and so on.*

Another student argued that the scenario 'Blue energy' appeals to students' daily life and therefore would be useful to provoke discussion in classroom setting:

I-MSB-2: *Uhm I think because uh we uh I think that a lot of kids from my class sometimes go to Zandvoort uh to have a nice swim and that they sometimes go by train. And I think that they themselves sometimes see that or something, that they drive past such a meadow and then they see a cow and then they just for example ate a cow yesterday or something and then uh yes.*

Int.: Yes.

I-MSB-2: *It [the topic sustainability] can uh be shown well with that yes.*

Furthermore, about the scenario ‘The Netherlands under water’ the opinions were divided. For example, one student argued that the scenario could help students to imagine different scenarios:

I-MSV-9: *Uhm... I think everyone then starts thinking in scenarios of wat could happen, what if this or what if that. And uhm that there will be a lot of reasons for that it would not happen. And, so to speak, to imagine that it just does not happen rather than that it could happen.*

While another student argued that it would be difficult to start a discussion about the situation described in this same scenario:

I-FSV-1: *Well, that [provoke discussion] seems difficult to me. Because yes you could talk about why it happens, how it can happen. But, basically if this were to happen it is just a fact that it happened.*

Also, the opinions on the scenario ‘Biodiversity’ were divided were one student argued in favor of usefulness due to a variety of topics in the scenario:

I-MSV-7: *Well because there, there are so many different topics in such a small text. So, you can talk a lot about it. Let us say you can talk about the government, you can talk about biodiversity, you can talk about everything.*

While another student argued that this scenario was unclear, which would make students think less about the future, and therefore would be less useful:

I-FSV-6: *Uhm... I think it makes kids think less about the future.*

Int.: *Okay and why do you think that?*

I-FSV-6: *Uhm because there is not much information to think about. I think it is still a little too unclear for some uh for some students to form opinions about it.*

Int.: *Okay.*

I-FSV-6: *And come up with ideas on that. Because some people who have been working on it for a while, who have been aware of the problem for a while and who also look into it, they will already have an opinion about it and they also think it is better. But the people who now, who are only a little bit busy with it now, they just don't have enough information I think.*

Discussion and conclusion

Students need to be able to use scientific, societal, and personal knowledge and values in order to effectively participate in decision-making and public debates about current SSIs. Therefore, education should inform and prepare students by focussing not only on knowledge but also on skills and clarifying and communicating values required to negotiate these

complex issues. This requires an adequate introduction of an SSI to generate students' interest and engagement. Making students more aware of the societal and personal values about sustainability-related SSIs will engage students in questioning and opinion-forming about these complex issues.

This study aimed to explore the educational potential of six future scenarios for introducing sustainability-related SSIs in science education and addressed the following main question and sub-questions of this research project:

What is the educational potential of future scenarios for introducing sustainability-related SSIs in lower secondary science education?

1. What kind of questions and emotions can future scenarios evoke in Dutch lower secondary school students?
2. What kind of underlying values and moral reasoning can future scenarios evoke in Dutch lower secondary school students?

Data to answer both sub-questions was provided by analysis of student interviews based on the emotions, questions, values and reasoning types evoked by the scenarios. Additionally, students' remarks to the three dimensions of sustainability, *People*, *Planet*, and *Prosperity*, and students' own perceptions on the scenarios' potential to evoke discussion provided deeper insight into the educational potential of the future scenarios.

Questions and emotions

Questions serve as a starting point and a motive for engagement in further personal, societal and scientific investigation into possible solutions for complex problems in SSIs. (Knippels & Van Harskamp, 2018). The future scenarios raised many questions in students, of which most were factual related (Table 4). This reveals students' interest and indicates that they want to know more about the future scenario. Note that not all scenarios raise the same types and numbers of questions. Overall, the scenario 'Future food' raised most students' questions and both 'The Netherlands under water' and 'Bye bye fashion!' the least. However, questions that are specifically focused on the story itself (narrative, image, words) and not on the situation or issue that is described in the future scenario suggest besides curiosity also distraction from the actual SSI in the scenario. For example, 'Blue energy' raised questions because the meaning of "energy-bundle" in the scenario was not clear and 'Future food' raised a lot of questions about the image in the scenario. Also, general knowledge questions, not related to the specific future situation or issue described in the scenario, imply a bad connection of the scenario to the students' prior knowledge. Therefore, questions focused on the story itself and general knowledge questions are not considered to indicate that students want to know more about the specific future situation or dilemma in the scenario. Factual, content-related questions in this study indicate students' intentions to gather more information about the specific SSI. All scenarios evoked such questions, with 'Future food' and 'Blue energy' raising the most compared to the other scenarios. This indicates that all scenarios have the potential to stimulate students' understanding of knowledge and the awareness of knowledge gaps, supporting the process of reasoning when negotiating SSIs (Sadler and Zeidler, 2005).

In order to have educational potential to introduce a sustainability-related SSI, future scenarios should raise both factual and normative questions. Despite the fact that not much normative questions were evoked, all scenarios except from ‘The future supermarket’ raised both factual and desirable questions in students. Although no firm conclusions can be drawn because of the small number of participants in this study, this may reveal a clear introduction of the controversial character of the SSI in all scenarios except from ‘The future supermarket’ (De Ruijter, 2013).

Furthermore, the scenario ‘Blue energy’ shows a remarkable difference between the questions evoked in the individual interview setting and in focus group setting. One aspect that could possibly influence this is the level of the student. This scenario is read individually by one student following pre-secondary vocational education and one student following pre-university level, of which the first student had no questions at all in reaction to the scenario. The difference in levels may relate to a difference in prior knowledge or a discrepancy in level of thinking between students, resulting in biased findings. However, the student following pre-university education also asked only few questions in reaction to the scenario which contradicts this argument.

Beside the potential of the future scenarios for evoking questions, various emotions were triggered by the future scenarios of which all scenarios evoked at least a range of five different types (Table 5). Emotions promote students’ ability to engage in SSIs and assist in taking various perspectives in the process of decision-making about these issues (Sadler & Zeidler, 2004; Sadler & Zeidler, 2005; Slegers, 2014). Students’ emotions in negotiating SSIs are therefore an important indication of underlying values and moral decision-making about these issues. In this study, most feelings raised in students were confusion, optimism, and sadness, which are all evoked by each scenario. Only two scenarios, ‘Bye bye fashion!’ and ‘Biodiversity’, raised anger in students and a feeling of surprise was only evoked by ‘Blue energy’ and ‘Biodiversity’. Confusion among students could possibly be explained by the complex content or future character of the scenarios. A feeling of confusion was mostly raised by the scenarios ‘Future food’ and ‘Bye bye fashion!’. This could possibly indicate that the content of these scenarios is more difficult to imagine and is experienced more remote from students’ daily life compared to the other scenarios.

A feeling of anger raised by ‘Bye bye fashion’ and ‘Biodiversity’ was in all cases directed at other people. This feeling arose from the frustration that others or people in general do not try hard enough to behave sustainably, according to the students. Even though the interviewer assured the students that there are no wrong or right reactions, the absence of a feeling of anger in students when reacting to other scenarios could possibly be attributed to a social pressure to respond in a desirable way. This assumption is reinforced by the fact that anger only was raised in students in individual interview settings, without the presence of classmates. Furthermore, ‘Biodiversity’ and ‘Blue energy’ were the only scenarios that raised a feeling of surprise, which was caused by an element in the future situation described that the students in question did not expect. The fact that this feeling was not raised by the other scenarios suggests that the content of these scenarios was more in line with the students’ views and assumptions about future developments in the field and therefore connect to the students’ perceptions.

Overall, 'Future food' and 'Biodiversity' were found to be most fruitful in triggering emotions in students, whereas 'The Netherlands under water' was found to be the least effective. Specifically, the scenarios 'Blue energy', 'The future supermarket', and 'Biodiversity' raise mostly a feeling of optimism and 'The Netherlands under water', 'Future food', and 'Bye bye fashion!' mainly trigger either sadness or confusion.

Underlying values and moral reasoning

Students' emotions in negotiating SSIs are an important indication of underlying values and moral decision-making about these issues. This study reveals that the future scenarios raised a broad range of underlying values in students. Overall, most values were related to 'care for nature' and 'autonomy', with the scenario 'Biodiversity' and 'Future food' raising most of such values respectively. The scenario 'Biodiversity' shows a remarkable difference in the values raised concerning 'care for nature', between the individual and focus group setting. This difference may be explained by the fact that the student clearly had thought about the topic before a lot already and therefore possibly had more experience in negotiating issues within this field than other students. However, no firm conclusions can be drawn because the prior knowledge of the students was not determined before the start of the interviews.

The difference in the types of values raised in each scenario could possibly be influenced by the topic of the scenario and the focus of the narrative. This may also be influenced by a difference between students in what appeals to them about the scenario. On the one hand, 'Biodiversity', 'Blue energy' and 'Bye bye fashion' show many instances of 'care for nature' which could possibly be explained by a focus of the narrative on the environment and polluting industries. On the other hand, 'The Netherlands under water', 'Future food', and 'The future supermarket' focus on human needs and living conditions which could possibly give a reason for the many instances of 'autonomy' and 'justice'.

Although no hard conclusions can be drawn because of limited participants, all scenarios seem to have potential for clarifying values since they raise a broad range of different values. Clarifying student values about sustainability-related SSIs improves communicating values and moral reasoning, which is required for well-informed decision-making and engages students in active and responsible citizenship. All future scenarios evoked a broad range of various types of reasoning, but students mostly relied on rationalistic and intuitive reasoning and less frequently used emotive reasoning. 'The Netherlands under water', 'Bye bye fashion!', and 'Biodiversity' evoked mostly rationalistic reasoning and intuitive reasoning was used mostly in reaction to the scenarios 'Blue energy', 'Future food', and 'The future supermarket'. However, in line with Sadler and Zeidler (2005a) and Van der Zande et al. (2009), students often relied on a combination of different types of reasoning throughout their reaction on the future scenarios. Overall, all scenarios evoked a combination of all three different types of reasoning with 'Blue energy' and 'Biodiversity' raising the most. All scenarios are therefore considered useful for improving moral reasoning and engaging students in the personal and social opinion-forming process. Further research is needed on aspects that possibly could influence the types of reasoning used by students.

Students' references to the three dimensions of sustainability

A broad range of current SSIs are expected to negatively affect the sustainable future (Gutierrez, 2015). Now, more than ever, education should enable student to acquire relevant knowledge, skills, and values to be able to commit to a sustainable future. In the context of education, *People*, *Planet*, and *Prosperity* are considered equally and should be in balance to be able to achieve sustainable development (Riess & Mischo, 2010; Purvis, Mao, & Robinson, 2019). Students covered all three dimensions of sustainability in their reactions to the scenarios 'The Netherlands under water', 'Blue energy', 'Future food', and 'Bye bye fashion'. 'The Netherlands under water' evoked most remarks to *People* compared to the other dimensions whereas both 'The future supermarket' and 'Biodiversity' evoked no references to *Prosperity* at all. The scenario 'Biodiversity' shows a noteworthy number of references to *Planet* in one of the individual face-to-face interviews, compared to the other scenarios. Just as with the remarkable instances of the value 'care for nature' in this specific student interview, this could possibly be explained by the fact that the student seems to already have more experience in negotiating issues within this topic than other students. However, no firm conclusions can be drawn because the prior knowledge of the students was not determined. The differences between the scenarios in students' remarks to the dimensions of sustainability may be influenced by the topic of the scenario. Although the scenarios involve scientific, societal, and personal themes, in 'The Netherlands under water' the element in the scenario related to human needs seems to appeal most to students since they refer most to *People*. In the other scenarios, students refer most to *Planet* which may indicate a strong element about the need to preserve the planet and natural resources. 'Bye bye fashion' and 'Future food' shows a higher number of remarks to *Prosperity* compared to the other scenarios. This could possibly be explained by the fact that both scenarios address an element about consumption, of either food or clothes. This may indicate a stronger element in these scenarios about meeting financial needs.

Overall, the scenarios that revealed a comprehensive reference to all three dimensions of sustainability were 'The Netherlands under water', 'Blue energy', 'Future food', and 'Bye bye fashion'. All scenarios show an outlier of remarks to one of the three dimensions, but in 'Future food' and 'Bye bye fashion!' the students' remarks were fairly divided when discussing the scenarios in focus group setting, compared to the other scenarios. This implicates a possible potential for these scenarios to be useful in sustainability education.

Educational potential

The educational potential of the six future scenarios for introducing sustainability-related SSIs is explored based on evaluation criteria derived from literature (see Table 9). Because not all evaluation criteria were recognizable in the interview transcripts, students' remarks to the three dimensions of sustainability and students' own perceptions on the scenarios' potential to evoke discussion were additionally used to explore whether the evaluation criteria were covered by the scenarios.

EDUCATIONAL POTENTIAL OF FUTURE SCENARIOS

Table 9 *Complementation of table 2. Description of criteria derived from literature (Table 1) and their application in the design and evaluation of six future scenarios. Criteria 1-3 are used as a guideline in the design of the future scenarios. Criteria 4-6 are used as a guideline in the evaluation of their educational potential to introduce sustainability-related SSIs in science education (gray cells).*

		Future scenario					
		The Netherlands under water	Blue Energy	Future food	Bye bye fashion!	The future supermarket	Biodiversity
	Topic	Water management	Energy policy	Food supply	Fashion industry	Food production	Biodiversity
Design criteria	1. They incorporate a complex SSI that is not too far in the future, that is open-ended and has no clear-cut solution.	Is flooding of The Netherlands inevitable?	Which strategy is best to generate energy in a sustainable way?	Should we have controlled food consumption, in favor of a more equal food distribution?	What is the best strategy to make the fashion industry more sustainable?	What is the best strategy to make the food production process more sustainable?	Which strategy is best to ensure the conservation of biodiversity?
	2. They provide a concrete and realistic view of the impact of science and technology that includes changes in what is	Human polluting behavior, like resource depletion, can contribute to	A more sustainable strategy to generate energy, via blue power	A controlled food production and distribution may maintain	A more sustainable fashion industry can decrease human	A more sustainable food production may involve cultured meet	More governmental control and less autonomy may help preserve

	regarded normal and provoke societal debate.	climate change with flooding as a possible consequence.	plants, can cause inequity and may affect living environments of marine animals.	overpopulation and decrease human autonomy.	autonomy and make original cities and “fashion” disappear.	and limit free will as a result of governmental control.	biodiversity-loss caused by human actions.
	3. They present involved stakeholders that react in a realistic way, comparable to similar previous situations.	Stakeholders: Authorities in resource extraction and waste disposal, Dutch and German citizens, tourists, farmers, animals.	Stakeholders: authorities in the field of water experts, Dutch citizens, citizens from water-poor countries, ship traffic, fisherman, marine animals.	Stakeholders: citizens from both under-privileged countries and “self-sufficient cities”, the government.	Stakeholders: present and former citizens, fashion designers, factory workers, employees of the new fashion network.	Stakeholders: citizens, supermarkets, meet industry, animals.	Stakeholders: Dutch citizens, animals, the government, provinces, municipalities, European countries.
Evaluation criteria	4. They raise awareness on the complexity and interdisciplinary character of SSIs by connecting scientific, societal, and	Clear introduction of the controversial character of the SSI	Clear introduction of the controversial character of the SSI	Clear introduction of the controversial character of the SSI	Clear introduction of the controversial character of the SSI	No clear introduction of the controversial character of the SSI,	Clear introduction of the controversial character of the SSI

<p>personal knowledge and values.</p>	<p>indicated by raising normative questions. Covers <i>People, Planet, and Prosperity.</i></p>	<p>indicated by raising normative questions. Covers <i>People, Planet, and Prosperity.</i></p>	<p>indicated by raising normative questions. Covers <i>People, Planet, and Prosperity.</i></p>	<p>indicated by raising normative questions. Covers <i>People, Planet, and Prosperity.</i></p>	<p>indicated by the absence of raising normative questions. Covers <i>People and Planet.</i></p>	<p>indicated by raising normative questions. Covers <i>People and Planet.</i></p>
<p>5. They stimulate future thinking about sustainability on a deeper level and stimulate students to ask questions.</p>	<p>Less realistic and therefore less potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask both factual and normative questions, most effective</p>	<p>Realistic and therefore potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask both factual and normative questions, most effective</p>	<p>Realistic and therefore potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask both factual and normative questions, most effective</p>	<p>Less realistic and therefore less potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask both factual and normative questions, most effective</p>	<p>Realistic and therefore potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask factual questions, most effective</p>	<p>Realistic and therefore potential to stimulate future thinking by supporting students to imagine a range of possible future scenarios. Stimulates students to ask both factual and normative questions, most effective</p>

		in individual context.	in individual context.	in focus-group context.	in focus group context.	in individual context.	in individual context.
	6. They support students in their opinion-forming process based on scientific sources and guide them in well-informed decision-making, by encouraging students to explore their values beyond their initial thoughts and emotions.	Least effective in raising both emotions (mainly sadness) and values (mainly justice). Indicates least potential to guide in decision-making.	Potential for raising emotions (mainly optimism), raises broad range of values (mainly care for nature). Indicates potential to guide in decision-making.	Most fruitful in triggering emotions (mainly confusion), raises broad range of values (mainly autonomy). Indicates potential to guide in decision-making.	Potential for raising both emotions (mainly confusion) and a broad range of values (mainly care for nature). Indicates potential to guide in decision-making.	Potential for raising both emotions (mainly optimism) and a broad range of values (mainly autonomy and harmless). Indicates potential to guide in decision-making.	Most fruitful in triggering both emotions (mainly optimism) and values (mainly care for nature). Indicates most potential to guide in decision-making.

Evaluation criterium 1: They raise awareness on the complexity and interdisciplinary character of SSIs by connecting scientific, societal, and personal knowledge and values.

Despite the fact that not many normative questions were evoked, all scenarios except from 'The future supermarket' raised besides factual also normative questions in students when reading the scenario in individual context. This may reveal a clear introduction of the controversial character of the SSI in all scenarios except from 'The future supermarket'.

Furthermore, all scenarios raised a broad range of values, with 'Bye bye fashion!' evoking all six different types and the other scenarios evoking a range of four or five different types of values in students. This diversity implies a comprehensive and complete picture of the SSI in the scenario. The use of values in reasoning might indicate increased students' awareness of societal and personal values about the introduced SSI, which is an important aspect of further opinion-forming and decision making about these complex issues. This is supported by the fact that in four out of six scenarios students mention all three dimensions of sustainability, indicating that students are aware of these different perspectives on the SSI when discussing the scenario.

Evaluation criterium 2: They stimulate future thinking about sustainability on a deeper level and stimulate students to ask questions.

As described above, all scenarios were found to stimulate students to ask questions, with 'Blue energy' and 'Future food' raising the most. However, these scenarios raised a relatively high number of questions related to the story or the image in the scenario, and not related to the specific issue described. This suggest that the story was unclear and therefore may distracts the students from the actual SSIs in the scenario. It was found that all scenarios except from 'The future supermarket' raise both factual and normative questions, indicating that these scenarios have both the potential to support the process of reasoning when negotiating SSIs as well as to clearly introduce the controversial character of the SSI in all scenarios except from 'The future supermarket'.

Implementing future thinking in sustainability education can stimulate students' engagement, communication of values, and enhance critical thinking skills (Jones et al., 2012). According to Wiek et al. (2011), the competence of sustainability thinking on future impacts in a problem-solving context is one of the most important aspects in sustainability education. This requires a focus on the future based on imagination and a structured exploration into how society and its physical and cultural environment could be shaped in the future (Jones et al., 2012). Future thinking has the ability to provide a more complete and realistic view of the impact of science and technology. Students' reactions to 'Bye bye model!' indicate that this scenario does possibly not stimulate future thinking because it does not present a realistic context to explore sustainability-related SSIs according to the students:

G-MSV-21: *I think it [the story] is quite unrealistic.*

G-FSV-23: *Yes.*

G-MSV-21: *Because it is about sustainability, but at the beginning he still talks about taking the scooter every day.*

G-FSV-24: *Yes.*

G-MSV-21: *Yeah, that is pretty unrealistic laughs.*

Other quotes indicate that the scenario ‘The Netherlands under water’ provides a more realistic view of the impact of science in the future situation described, according to one of the two students:

G-MSV-22: *Well, I think it is realistic, but I would not like it.*

G-FSV-24: *Well, I do not think it is very realistic, because uhm, they are really quite professional with building dikes and such. So, I think that such a flood does not just happen and also that they are doing quite well with reusing everything and so on. I do not think that it, just say, that that water would happen just like that. Maybe yes, but then I think those dikes are well adapted to that and so on.*

Some students argued that the scenario ‘Blue energy’ appeals to students’ daily life and that ‘The Netherlands under water’ could help students to imagine different future scenarios. In reaction to the other scenarios, students did not make comments on whether they found that the future scenario presented a realistic view or not. However, students seem to take each scenario seriously and commented on it thoughtfully. Students showed deliberate reactions and serious discussions in focus group setting about the future situation in the scenario and how that would be. Although no firm conclusion can be drawn because of the small-scale nature of this study, this suggests that all scenarios could be useful for exploring possible future scenarios, predictions, and options of choices and alternatives for students to reflect on and therefore have the potential to stimulate future thinking. Based on the comments of students about the scenarios’ potential to provide a realistic view, the scenarios ‘The Netherlands under water’ and ‘Future food’ are considered to be most suitable for supporting students in imagining possible, probable, and preferable futures. This is for example pointed out by a student about the scenario ‘Future food’:

I-MSV-3: *Because you, you can discuss this [the development described in the scenario] pretty well because, of course it is something that could happen in the future and then you can figure it out... why and why not.*

Int.: *Yes. And why and why not, what exactly are you then talking about?*

I-MSV-3: *So, for example I think it could happen because shrugs, because there is a lot of overpopulation. But for example, my buddy does not think that because uhm the government would not do that.*

Evaluation criterium 3: They support students in their opinion-forming process based on scientific sources and guide them in well-informed decision-making, by encouraging students to explore their values beyond their initial thoughts and emotions.

When students show values and emotions in their reasoning this can be seen as a positive thing because emotions and values are an important part of the emotional deliberation approach to opinion-forming (Slegers, 2014). This study reveals that the future scenarios raised a broad range of emotions of which all scenarios evoked at least a range of five different types of emotions. This suggests that the scenarios support students’ ability to engage in SSIs. ‘Future food’ and ‘Biodiversity’ are most fruitful in triggering emotions in

students, with raising mostly a feeling of confusion and optimism respectively. Students' emotions indicate a potential of the scenarios for helping students to take various perspectives in the process of decision-making about SSIs (Sadler & Zeidler, 2004; Sadler & Zeidler, 2005; Slegers, 2014). Raising emotions in negotiating SSIs indicate underlying values and moral decision-making about these issues. In general, it can be concluded that the future scenarios have potential to encourage students to explore their values beyond their initial thoughts and emotions.

Table 10 shows an overview of the future scenarios based on their educational potential. Plusses and minuses are assigned to the scenarios, based on the number of instances of the specific category in the student interviews. '-' indicates < 10 instances, '-/+' indicates 10-20 instances, '+' indicates 20-30 instances, and '++' indicates > 30 instances of the specific category in the student interviews. Note that both questions that are not related to the content of the future scenario and feelings of confusion and entanglement are not included in the determining of the effectiveness of the scenarios, because these aspects indicate distraction from the actual dilemma in the scenario.

Table 10 An overview of the educational potential of the future scenarios for introducing sustainability-related SSIs, based on their effectiveness to raise questions, emotions, reasoning and values. '-' indicates < 10 instances, '-/+' indicates 10-20 instances, '+' indicates 20-30 instances, and '++' indicates > 30 instances of the specific category in the student interviews. Irrelevant questions (not related to the SSI) and emotions (confusion and entanglement) are not included in this overview.

	Future scenario	Questions	Emotions	Values	Reasoning
1.	The Netherlands under water	-/+	-/+	-	+
2.	Blue energy	+	+	-/+	++
3.	Future food	++	-/+	+	++
4.	Bye bye fashion!	-/+	+	-/+	+
5.	The future supermarket	-/+	+	-/+	+
6.	Biodiversity	-/+	+	+	++

Summary

It can be concluded that the future scenarios evoke a broad range of emotions, questions, values, and types of reasoning in students and can provide students with a realistic future scenario to reflect on and stimulate thinking about future possibilities and situations. Specifically:

Questions

'Future food' and 'Blue energy' raise most factual, content-related questions and therefore are the most fruitful in stimulating students' understanding of knowledge and the

awareness of knowledge gaps which supports the process of reasoning when negotiating SSIs. All scenarios except from 'The future supermarket' raise normative questions and therefore have potential to provide a clear introduction of the controversial character of the SSI.

Emotions

'Blue Energy', 'The future supermarket', 'Biodiversity', and 'Bye bye fashion!' are most fruitful in triggering emotions in students, with the first three raising mostly a feeling of optimism and the last raising mostly a feeling of sadness.

Values

'Biodiversity' and 'Future food' are most effective in raising values in students and trigger mostly values related to 'care for nature' and 'autonomy' respectively.

Reasoning

'Blue energy' and 'Biodiversity' are most useful for improving moral reasoning and engaging students in the personal and social opinion-forming process, with raising a broad range of different types of reasoning.

Additionally, some scenarios cover all three dimensions of sustainability in a fairly divided way. For these reasons, it can be concluded that future scenarios have educational potential for introducing sustainability-related SSIs with a varying effectiveness and focus among the scenarios.

Future scenarios should be used in science education for introducing complex sustainability-related SSIs. Future larger-scale research and research on teaching and learning methods for implementing future scenarios in education, will explore how future scenarios can be used for further investigation into opinion-forming and decision-making on sustainability-related SSIs.

Limitations

This study has some limitations. First, this small-scale study included a limited number of participants from two different schools. Also, the future scenarios were only read by two students individually, followed by one focus group interview. The small-scale character of this study makes it likely that different participants from different schools will provide different outcomes and that an exceptional student may bias the results. Second, no prior knowledge or experience in negotiating SSIs is determined before start of the student interviews. The results implied that some students in this study clearly had a lot more prior experience with thinking about the scenario topic than an average student is expected to have. Furthermore, they possibly had more experience in negotiating SSIs. This could probably have influenced the results in this study. Finally, in order to stimulate students to react truthfully and not in a desirable way, the interviewer mentioned before the start of the interviews that there are no wrong or right answers or reactions to the scenarios. However, there is a possibility that the students' reactions to scenarios with regard to environmental

awareness, responsibility of sustainable development and/or behaviour, and environment-related activities were socially desired responses. However, the aim of this study was to determine whether these scenarios had educational potential in raising questions, emotions, and moral reasoning and we found that they did.

Implications and recommendations

The future scenarios have educational potential to introduce a sustainability-related SSI in education and therefore can provide a suitable approach for teachers to deal with such an issue in the classroom. The different future scenarios each raised a varying combination of questions, emotions, values, and reasoning types. Overall, for teachers it is recommended to carefully select one scenario or to combine two or more scenarios depending on the desired effect and other preferences, since they together cover a broad range of questions, emotions, values and reasoning types and dimensions of sustainability. This is also suggested in follow-up research on designing and testing teaching and learning strategies for implementing the scenarios in education. Before using the scenarios some adjustments to the scenarios are recommended. Concerning 'Blue energy', some students indicated that it was not clear from the text what "energy-bundle" means, which resulted in misinterpretations and distraction from the actual SSI. It is suggested to explain or exclude this definition from the scenario, as it is not seen as an essential element. Despite the fact that the scenario 'Biodiversity' in general was interpreted well and experienced as interesting and fun by the students, some indicated that a few words were not always clear to them. These words include the descriptions in the legend "recreatief and klimaatadaptief". Therefore, it is suggested to explain or replace these words. The scenario 'Future food' raised a lot of questions in students regarding the image in the scenario. These questions seem to distract students from the actual dilemma. It is suggested to add guiding questions in the development of teaching and learning strategies for implementing this scenario in education, because during the student interviews this appeared to be effective in keeping focus on the actual dilemma. In de interviews about the scenario 'Bye bye fashion!', the students highlighted the contrast of on the one hand the person in the text who goes to school by scooter and on the other hand the focus on sustainability and sustainable behaviour in the rest of the story. This didn't seem to be disturbing but was slightly distracting from the actual dilemma. For further research it is recommended to replace the scooter with a bike or another more sustainable vehicle to refine the scenario.

This study reveals an educational potential of the six future scenarios for introducing a sustainability-related dilemma in secondary education (as part of the SSIBL-approach), for they stimulate students' interest and engagement. In line with previous research of Knippels & Van Harskamp (2018), it is recommended to give students the opportunity to form initial thoughts and opinions before discussing them with other classmates. Moreover, for students to feel invited and welcome to express their initial thoughts, emotions, and questions, an all-embracing classroom environment is required. This is emphasized by the appearance of a broad range of emotions, values and types of reasoning.

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Appendix 1

Future scenario 'Biodiversity'

Meer groen in Nederland



Door menselijk handelen neemt de variatie van het leven op aarde snel af. Het was daarom onze verantwoordelijkheid om deze achteruitgang te stoppen. De indeling van Nederland is in handen van de overheid. Provincies en gemeenten hebben niets meer te zeggen. We moeten onze keuzes verantwoorden aan andere landen in Europa, of we dat nu leuk vinden of niet, want biodiversiteit is grenzeloos.

Appendix 2

Future scenario 'Future food'

Eten in de toekomst



Goede leefomstandigheden lossen overbevolking niet op. Inwoners van arme landen trekken naar steden, om het uitzichtloze platteland te ontvluchten. Maar omdat de steden daar overvol zijn trekken ze door naar Europa. Mensen verhuizen naar de zelfvoorzienende steden, hopen op een rustiger en beter leven. Dit versterkt de overbevolking.

Kas leeft in zo'n zelfvoorzienende stad, een van de velen nu in Nederland. Hier is alles zo geregeld dat je als inwoner zelf bijna niet hoeft na te denken. De overheid zorgt voor precies genoeg voedsel per dag. Kas heeft eigenlijk nooit vraagtekens geplaatst bij de keuzes die voor hem worden gemaakt. Maar dit is veranderd sinds de overheid een grote fout heeft gemaakt. De gevolgen waren groot voor de voedselproductie. "Ik vind dat mensen zelf moeten kunnen kiezen wat ze eten", zegt Kas. Hij kijkt zijn moeder boos aan. "Hoe ver wil je gaan?" Haar stem klinkt kalm en verstandig. Met de manier waarop we nu voedsel produceren, kunnen we veel meer mensen voeden dan er leven. "Straks vind je ook nog dat mensen moeten kunnen kiezen hoeveel kinderen ze krijgen, of waar ze willen wonen, of wanneer ze willen sterven."

Appendix 3

Future scenario 'Blue energy'

Blauwe Energie



Zo, de laatste schooldag achter de rug! Ik heb vakantie en het begint al goed. De zon straalt aan de hemel. Ik zit in de trein die mij naar het strand in Zandvoort brengt. Ik voel mijn telefoon trillen in mijn broekzak en verwacht een appje, maar wanneer ik check blijkt het een laatste herinnering om hem weer een keertje op te laden. Als ik straks in ons vakantiehuisje aankom kijk ik meteen of we nog energie-minuten over hebben. Even een herinnering in mijn telefoon zetten. Ah nee, hij valt uit! Altijd hetzelfde liedje aan het einde van de maand. Misschien moet ik mijn bundel nu toch maar eens verhogen.

Om de tijd dan maar op een andere manier door te brengen, kijk ik wat naar buiten. Het uitgestrekte water maakt mij rustig. Vroeger voeren er nog boten, maar sinds ze het water uit de Waddenzee en het IJsselmeer gebruiken voor blauwe energie centrales, zijn alle riviermondingen afgesloten voor de scheepvaart. Sommigen zeggen zelfs dat hier ooit vissen in zwommen. Dat er vissersboten waren die hele netten vol met deze wilde vissen uit het IJsselmeer schepten. En we aten het nog op ook! Alleen al bij het idee draait mijn maag zich om.

Ik rij langs de grote energiecentrale aan het einde van de Afsluitdijk. De installaties zijn aangesloten op het elektriciteitsnet, zodat iedereen de opgewekte stroom kan gebruiken. In veel andere landen is het wel anders. Daar hebben ze in de hete perioden van het jaar maar heel weinig water, soms niet eens genoeg om te drinken, laat staan om er energie mee op te wekken. Daar zou je, als je geluk hebt, maar een uur per week je telefoon op kunnen laden. Gelukkig woon ik in Nederland, waar we ons geen zorgen hoeven te maken over de beschikbaarheid van water om energie mee op te wekken. De Nederlandse waterdeskundigen zijn dan ook gewild over de hele wereld.

Hopelijk kan ik mijn telefoon nog net een keer helemaal opladen voordat ik mijn limiet bereik. Wanneer de trein een half uurtje later het station van Zandvoort binnenrijdt, besluit ik vanaf volgende maand mijn energie-bundel te verhogen.

Appendix 4

Future scenario 'The future supermarket'

Boodschappen doen in de toekomst

Vandaag ben ik jarig! We luisterden verjaardagsliedjes onderweg naar de supermarkt. Ik mag een taart uitzoeken! Alleen als je jarig bent kan je nog een ouderwets 2020 taartje eten.

In de supermarkt lopen we meteen door naar het verjaardagspad. Ik laat mijn ID-kaart zien en mag naar binnen. Thuis hebben we afgesproken dat ik er een van de onderste plank mag kiezen. Als ik een chocolade- en aardbei-smaak uit het schap pak, informeert het scherm mij over alle ingrediënten en afkomst, ecologische voetafdruk en allergieën. Ik kijk op en zoek de ogen van mijn moeder. Ze zal wel alvast zijn doorgelopen. Ik kies het chocoladetaartje en loop het pad uit.

Ik volg de bordjes naar de kweekveesafdeling. Deze ruimte gevuld met karbonades, speklapjes en schnitzels bezorgde mij vroeger altijd kippenvel. Maar sinds ze de dieronvriendelijke productie van vlees verboden hebben, ben ik niet meer vegetarisch. Tegenwoordig maken ze onze stukjes vlees met de nieuwste kweekveestechologie. Op de virtuele wand kun je het hele proces volgen, van laboratorium tot het stukje vlees op je bord. Het slachten van dieren is niet meer nodig. Sterker nog, het dier waar het vlees vandaan komt staat hier virtueel op de kweekveesafdeling waar mijn moeder al een mals stuk van de koe aan het uitkiezen is.

We halen snel nog even de rest van de boodschappen voordat we terug naar huis gaan. Ik leg mijn vinger op de scan en mijn DNA-profiel verschijnt op het display. Ik pak mijn voorraad dagelijkse shots voor deze maand dat uit de automaat tevoorschijn komt. Het persoonlijke voedingsadvies zorgt ervoor dat er precies genoeg is voor iedereen. Eten weggoaien, is niet meer van deze tijd. Dat is zó 2020. Yes! Deze week weer een paarse, dat is mijn lievelingssmaak!



Appendix 5

Future scenario ‘Bye bye fashion!’



Bye bye mode!

Het is 6:45 uur. De wekker gaat voor de laatste keer deze week. Ik sta op en schiet soepeltjes in mijn T-shirt. Wanneer ik ook mijn broek aan trek word ik geconfronteerd met het feit dat ik vaker op de fiets naar school moet gaan in plaats van met de scooter. Met moeite krijg ik hem dicht. Ik besluit dat vandaag een sportieve dag wordt, pak mijn fiets en race richting school.

De saaie en kleurloze route door de stad herinnert mij aan toen ik besloot niet meer te willen fietsen. Er is gewoon niks aan! Dat was vroeger blijkbaar wel anders, als ik de verhalen van mijn opa moet geloven. Toen waren er veel mensen op straat, wandelend en op de fiets. Op zoek naar de nieuwste modetrends in de kledingwinkels. Afkomstig van fabrieken hier ver vandaan. Ik kan mij er niet zo veel bij voorstellen, maar het klinkt best gezellig. Vroeger was er iemand die een kledingstuk bedacht en ontwierp. Daarna duurde het nog een jaar voordat de duizenden kledingstukken zijn gemaakt en naar de verschillende lokale kledingwinkels zijn gebracht, klaar om door ons gepast en gekocht te worden. “Mode” en reclame was een trucje om deze (alweer oude) kledingstukken alsnog verkocht te krijgen.

De ouderwetse, vervuilende en verspillende kledingindustrie is al lang geleden geüpdate naar een duurzame productiemethode. Nu bestellen we alles gewoon bij de D&M. Eerst wordt gevraagd wat we nodig hebben. Je kiest online je maat en de kleur die je wilt. Dan pas wordt het geproduceerd. Het wordt verstuurd via het netwerk en om de hoek 3D geprint! Onze kleding hoeft niet meer de hele wereld over.

Ik ben nog geen 10 minuten onderweg en het kunstleer plakt al aan mijn rug. Sinds ze kunstmatig leer kunnen maken en kunnen kleuren met behulp van bacteriën, hebben we gelukkig nog iets te kiezen! Want soms verveelt het wel, altijd maar hetzelfde model en altijd maar dat kunstleer. Mijn gedachten dwalen af naar de tijd dat iedereen nog verschillende kleding droeg. Toen er nog mensen in de fabrieken werkten. Ik ben blij dat we nu bijdragen aan een duurzamere wereld.

Oh! Ik schrik van de schoolbel in de verte. Ik haast mij het laatste stukje, het plein op naar het fietsenhok. Ik rem en kom tot stilstand. Met een zwaai slinger ik mijn been over de stang, wat een verontrustend geluid veroorzaakt. Ik kijk naar beneden en zie tot mijn schrik het gevolg van mijn gebrek aan beweging de afgelopen tijd. Er zit een scheur in mijn broek!

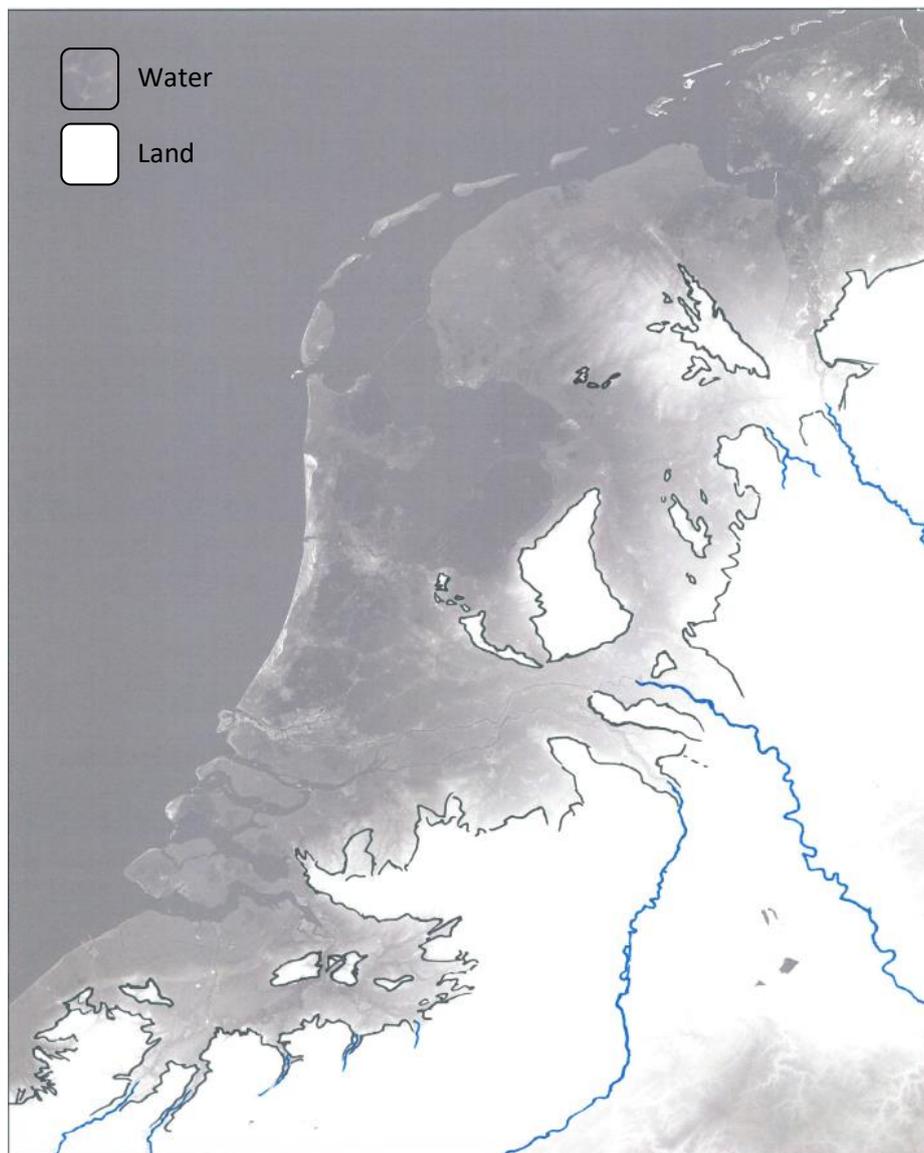


Universiteit Utrecht

Appendix 6

Future scenario 'The Netherlands under water'

Nederland onder water



We gooien tegenwoordig niets meer weg en gebruiken alles opnieuw. Ook de grondstoffen die we al uit de aarde hebben gehaald, gebruiken we steeds weer opnieuw. Zo zorgen we dat we geen afval meer hebben, omdat we het afval opnieuw gebruiken. Toch heeft dit niet alles kunnen voorkomen. Het westen van Nederland is verleden tijd. Ook veel toerisme en landbouwgrond is verdwenen. 90% van onze inwoners woont nu in Duitsland. Het enige wat we nog hebben van de steden die nu onder water liggen, zijn foto's en filmpjes die toen gemaakt zijn.



Universiteit Utrecht

Toekomstscenario t.b.v. masteronderzoek Lotte Esmeijer
Afbeelding © Kim Cohen. Schuttenhelm, R. (2019, 5 februari). De zeespiegelstijging is een groter probleem dan we denken.
En Nederland heeft geen plan B. Geraadpleegd op 23-11-2020, van <https://www.vn.nl/zeespiegelstijging-plan-b/>

Appendix 7

Interview scheme

The aim of the pilot interviews

The goal is to explore:

- Students' reactions;
- Connection to students' daily life;
- The coherence of the story;
- The readability of the text.

In this pilot test, the students are asked to read a future scenario, answer asked questions and elaborate given answers. This pilot interview serves as a possibility to refine the interview scheme and optimize the future scenarios. In the pilot, the interviews were at least carried out up to and including part 3 of **Initial reactions**, to explore the initial thoughts and feelings about the scenario. Specific questions in **In-depth information** about the future scenarios were tried out in an investigative way, depending on students' reactions and course of the interview.

The aim of the individual face-to-face interviews and focus group interviews

In the face-to-face interviews, the students are asked to read a future scenario, answer asked questions and elaborate given answers. These interviews serve as a possibility to explore the answers to the sub-questions:

1. What kind of emotions and questions do the Future Scenarios evoke in Dutch lower secondary school students?
2. What kind of underlying values and moral reasoning could be evoked by the Future Scenarios in Dutch lower secondary school students?

In the individual face-to-face interviews and focus groups, the interviews were carried out up to and including part 3 of **Initial reactions** and specific questions in **In-depth information** about the future scenario in question.

Background information:

Date:

Male/female:

Grade (year and level):

Age:

Duration of the interview:

The study

Thank you for participating in this study. This interview is part of my master's thesis research at the University of Utrecht. I design short texts in which a sustainability-related issue is introduced, with the goal to reinforce science education. These texts describe a scenario in the future. Keep in mind that this is a possible scenario and not a prediction of the future. For my research it is important to find out what you think about these texts/what your opinion is. Thus, there are no wrong or right answers.

The interview**Initial reactions**

1. Do you have any questions before we start?
2. I sent you a text in the chat in Teams/I gave you a text. You now get time to read this text in silence. Please indicate when you are ready, then I will ask you some questions about it.

Student reads the future scenario

3. What do you think about this text?

Follow-up question depending on the answer of the student:

- I saw you..., why did you do that?
- Why do you think so?
- Can you describe how you feel?
- What do you mean with that?
- If the student reacts to much on the general meanings, of for example sustainability: if you take this specific example, how do you think about that?
- Do you have a certain feeling about this?
- What questions do you have?
- What kind of questions are evoked by this scenario?

In-depth information

Specific questions about the future scenario 'Blue Energy'.

- How do you think about this strategy to generate energy, as a solution for the energy-problem?
- How do you think about the difference between countries in availability of blue energy?
- Do you think that we should generate energy in this way (blue energy plants)?

Specific questions about the future scenario 'The future supermarket'.

- How do you think about cultured meat? Would you eat it yourself?
- How do you think about this solution to feed everyone in a sustainable way?
- Would you consider it okay for what you eat to be checked (1x a year cake, shots), if that means that everyone can be fed in a sustainable way?

Specific questions about the future scenario 'Bye bye fashion!'.

- Do you think this is a good strategy to make the fashion industry more sustainable?
- Would you be okay with having less choice in clothing if that means it is made in a sustainable way?
- Do you think this Is a good way to make the fashion industry more sustainable?

Specific questions about the future scenario 'The Netherlands under water'.

- Would you like to be one of the people who has to move to Germany? Why/why not?

Specific questions about the future scenario 'Future food'.

- How would you feel when your food choice is determined for you?
- Would you drink such drinks (in the text) yourself if we had them later?

Specific questions about the future scenario 'Biodiversity'.

- How do you feel about the statement that humans are responsible for stopping the decline in biodiversity?
- How do you think about this solution for the biodiversity-problem (= decline in biodiversity)?

Conclusion

3. Do you think using this future scenario is a good way to introduce sustainability in the classroom?
4. Are there other things you want to say or ask?

Thank you for participating in my study via this interview!

Appendix 8

Coding scheme

Questions

Content future scenario	
Con-a	About the (unclear) scenario-specific content (the story itself). Not about the process behind the future situation that is described.
Con-b	About the future application of the situation in the scenario and how that would be.
Knowledge about specific SSI in the future scenario	
Kno-a	About the functioning of a process/mechanism: how does this work?
Kno-b	About the state of the development in this field: how is this now and how could something like this happen in the future?
General knowledge	
Gen	About general knowledge (about sustainability), not related to the specific scenario.
Desirability	
Des	About what is good or what should be allowed: is this what we want?

Emotions

Joy	Joy, gladness, feeling of joy, amused, optimistic, gratitude.
Opt	Optimism, satisfaction, contentment, positive, pleased.
Ang	Anger, irritability, annoyance, frustration, rage, envy.
Fea	Fear, feeling of oppression, fear, insecurity, bad, frightened, shocked, worry, anxiety.
Sur	Surprise, astonishment, amazement, state of mind when perceiving something unexpected, wonder.
Dis	Disgust, aversion, nausea. Contempt, often towards an individual, group or ideology.
Cur	Curiosity, interested, intrigued (when the student indicates that they want to know more but not coded when interest is shown only by asking a question).
Conf	Confusion, strange, weird, hard to imagine. In reaction to the future situation described, to the content of the scenario.

Ent	Entangled, vague, confounded. In reaction to unclear information, text, image.
Pit	Pity, sympathy, compassion, sympathetic sorrow evoked by the suffering of others.
Sad	Sadness, mental pain, suffer, despair, unhappiness, shame, disappointment, discontentment, uncomfortable, the feeling of dissatisfaction that follow the failure of expectations or hopes to manifest.
Non	None, students don't care.

Reasoning

Rationalistic	
Rat	Reasoning with reason-based considerations, using logic. Can be either hypothetical or under assumption, but still logically reasoned or empirical using proven facts.
Emotive	
Emo	Reasoning with care-based considerations like empathy, considerations directed at others.
Intuitive	
Int	Reasoning with considerations based on immediate reactions to the context of the scenario, 'immediate knowing', without conscious awareness of having gone through steps of search or weighting evidence, self-evident (being evident without any need of proof). Could be a consideration without further explanation, as for the student it does not need any further explanation.

Values

Aut	Autonomy: respect for free will/self-determination (freedom and agency). Respect for privacy.
Ben	Beneficence: doing good, an act that does someone good, promote the well-being of others.
Har	Harmless: do no harm, avoid harm, do not harm others/other animals.
Jus	Justice: fair sharing of benefits and burdens, social equity. Everyone is entitled to the same. For example, equal opportunities, child survival, education, commitment to social justice and equity.
Car	Care for nature: Preserve the planet, reinforce environmental resources.
Res	Responsibility: We share moral obligations to both others and to broader moral standards, we are all entitled to the same and should take our responsibility.

Dimensions of sustainability

Peo	People: meeting human needs (equal opportunities, child survival, education, belief that people can make a difference). Meeting equitable and sustainable management of natural resources for the benefit of all humanity (institutions, social capital, provinces/regions, reducing hunger and poverty).
Pla	Planet: refers to the need to preserve the planet (shared, human responsibility and respect for nature) and the use of resources in a way they will not be depleted.
Pro	Prosperity: refers to economic performance, profit, and the production and consumption of welfare. Includes productive sectors and meeting any individual needs in financial context.

Usability

Yes	Usable to provoke a discussion in classroom setting, according to the students themselves.
No	Not usable to provoke a discussion in classroom setting, according to the students themselves.