

Article

Relevance of Life-Cycle Assessment in Context-Based Science Education: A Case Study in Lower Secondary School

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Abstract: The article introduces a science education intervention using life-cycle analysis of consumer products. The intervention aims to promote lower secondary school students' science career awareness and interest toward science studies. In this study, two lower secondary school teachers planned an intervention on life-cycle analysis, which aimed to be relevant for the students from an individual, societal, and vocational perspective. The study then examined how students perceived the relevance of the intervention, based on classroom observations, students' life-cycle presentations, questionnaire responses, as well as interviews. The findings indicate that students found life-cycle assessment to be a relevant topic both from an individual and societal perspective. However, findings on vocational relevance were two-fold, as students gained knowledge on different occupations, but this did not seem to directly affect their future career aspirations.

Keywords: life-cycle assessment; inquiry-based learning; careers; science education; circular economy

1. Introduction

During the past few decades, many studies have shown that science education is unpopular among young students, seen, for instance, in the low enrolment levels to upper secondary school science courses [1] and students' non-science related future career aspirations [2–4]. Researchers have suggested that one of the reasons why science education is unpopular among students is that students perceive science education to be irrelevant to their everyday lives and to society [5–7]. Therefore, for the past few decades, scholars have discussed and examined ways to make science education more relevant for students.

Though scholars and stakeholders agree that science education needs to be relevant, there has been ambiguity on what is meant by relevant education and to whom it should be relevant. Historically, science education has had a strong focus on giving students tools they would need if they wanted to pursue a career in science, medicine, or engineering [8]. With this goal in mind, the main focus of science education was to provide students with vocational relevance, where vocational relevance was predetermined by the needs of the scientific community [5]. However, as not all students will become scientists, such a focus makes science education more or less irrelevant to the majority of students [9]. To deal with this issue, in the late 1960s, science education began to focus more on a “Scientific Literacy for All” [10,11] approach. Gradually this transformation led science education to focus more on helping students become scientifically literate citizens who can participate in socio-scientific discourse [12], something relevant to students, as they are often keen to consider their role in society [13].

This study introduces an intervention focusing on life cycle assessment as a context in science education and examines students' and teachers' perceptions on the relevance of the intervention.

1.1. Relevance in Science Education

Science education has two main approaches—a context-based approach and a societal-oriented approach. Both approaches attempt to make science education meaningful and relevant to students. The goal of both of these approaches is that science education would help achieve general skills for societal participation [14,15].

1.2. Different Dimensions of Relevance

To take into consideration the different dimensions of relevance, researchers have suggested that relevant education needs to be relevant to the individual, to society, and to the future vocation of the student [5,16,17]. In this categorization, individual relevance is something that meets the direct needs of the student, for example by providing them with skills and knowledge to feed their curiosity and understand the world around them. Societal relevance gives tools to become an active citizen and understand the world they live in. Vocational relevance includes giving knowledge and skills that may be useful for the student's future career. Vocational relevance can be further divided into two subsections—knowledge gain and future aspiration [18]—as students may gain interesting knowledge about careers during science education, but it may not affect their future career aspirations, which the student may have already determined at an earlier age [2,4]. In addition to the three dimensions (individual, societal, and vocational) of relevance, Stuckey et al. [5] have included two additional ranges to their model, which are the present–future range and the intrinsic–extrinsic range. According to them, science learning becomes more relevant when learning has a positive consequence on the student's life. These can include dealing with issues that meets the student's personal interests or educational demands (present) and the anticipation of future needs [5]. The intrinsic–extrinsic range includes aspect, such as student's interests and motives (intrinsic) and expectations set by family or society (extrinsic).

This study introduces a context-based intervention that was created to address all three dimensions of relevance to and explores how relevance of the intervention may be perceived in different ways by students and teachers. The intervention was created for and tested on grade 9 students in Finland, and it focused on a products' life-cycle assessment using a context-based learning approach.

1.3. Context-Based Learning

Context-based learning (CBL) has been carried out to increase the relevance of science education to students' everyday lives [5,7,19–21]. CBL aims to introduce students with contexts relevant to their present lives, but also future situations they may encounter in everyday life or their future careers. These can include context related to technological developments, the industry sector or advances in scientific research and innovations, to mention a few [22]. CBL interventions have been shown to have a positive effect on students' attitudes, interest and motivation in science education [21,23]. Contexts may be especially useful when used as a starting point for science teaching, as they improve attitudes towards science even though students might have different levels of interest and motivation towards the context [19,22]. For example, Krapp and Prenzel [23] found that when students in school physics can recognize a direct connection to practical life situations, their interest does not decrease and may even increase. Though all contexts do not have the same effects on all students, the use of contexts as a starting point in science teaching, particularly from the viewpoint of attitudes, has been supported [22]. Context-based learning also has the potential to contribute to vocational orientation and promote learning in the societal dimensions of science. This provides learners with opportunities to learn how to structure scientific knowledge, therefore contributing to all three dimensions of relevance [5].

1.4. Life-Cycle Assessment as a Context for Learning

Life-cycle assessment (LCA) is a useful way to bring context-based learning into the classroom. Typically, LCA is used to assess the environmental burden and health impact of a product, throughout a products' life-cycle, from acquisition of raw materials to utilizing waste [24,25]. In education, LCA can also have a strong emphasis on sustainability in a wider sense, as it can also be used to discuss issues, such as values, human rights, [26,27] and how psychology, norms, and marketing may affect our consumption. Examining a products' life-cycle is also closely related to circular economy and can help students develop system thinking, [28]. Furthermore, LCA is also related to science ethics and moral awareness [29] and is often used to evaluate how ecological a product is—for instance, from the perspective of a carbon or water footprint.

However, research on the use of LCA in education is scarce [26,27]. In a recent review article [26], only nine studies were found to examine the use of LCA in education, most of which were carried out in higher education with engineering students. Several new articles have appeared since the review, but the research field remains underdeveloped. The same can be said on research on education on circular economy [30].

Despite the lack of research, existing studies have shown many benefits of using LCA in education. For instance, LCA can support scientific development [31], increase students understanding and awareness of environmental issues [32], motivate students [33], and increase interest toward science [34]. Several of the studies have also shown that LCA can help increase awareness and interest towards new career options [32,34].

Unfortunately, most of these studies have been conducted in higher education. To our knowledge, only three studies have been conducted on the use of LCA in the K–12 level, all conducted by Juntunen and Aksela [35–37]. These studies found that LCA improves students' argumentations skills in scientific and ecological issues. The studies also found that ninth grade students enjoyed learning about sustainability, contrary to previous studies that show that ninth grade students in Finland are generally not very interested in environmental issues [38]. This contradiction may be due to the fact that LCA issues contain a societal and ethical aspect—something students often find interesting [29,39].

LCA should be incorporated into secondary education more strongly and present how scientific, societal, health, environmental, and vocational issues can all be addressed through LCA [27]. Some of the reasons to incorporate LCA to secondary school is that consumption habits developed at a young age can have a major influence on how one consumes as an adult (e.g., [40,41]) and because students can also influence the consumption habits of their parents (e.g., [42]). In general, LCA can also help students gain a broader understanding of how the world works, helping them develop skills needed as citizens and in future occupations. The importance of examining products' life-cycles in secondary school has also been acknowledge by some private organization, such as the Ellen MacArthur Foundation [43] and Finnish think tank Sitra [44], both of which have helped develop teaching and learning resources on the topic.

1.5. Aim of Study

This study examines how teachers and students perceive the relevance of an intervention on life-cycle assessment. More specifically, this study examines which aspects of the intervention on LCA do students find relevant from an individual, societal and vocational perspective and how this is in line with the teachers' views.

2. Methodology

2.1. Context and Participants of the Study

The data for this case study was collected as part of a larger EU project with the title “Promoting Youth Scientific Career Awareness and its Attractiveness through Multi-stakeholder Co-operation” (MultiCO). The aim of the MultiCO project was to promote students' awareness and interest in science

studies and career opportunities. Participants in this case study are two female science teachers, with over 20 years of teaching experience, and their 32 secondary school students in grade 9 (ages 15–16).

2.2. Description of Intervention

A context-based approach and LCA was used to create an intervention. Before this case study, the teachers created four career-based interventions around different themes as part of the MultiCO project. Despite their efforts, the teachers struggled to make the interventions related to science careers interesting for the students. Based on their experience, the teachers realized that they need to increase the relevance of their teaching so that the career-based theme would

- Be clearly structured linking content and careers;
- Include several careers rather than only one;
- Include students' own activities related to careers;
- Include visits (out of school) that need to include tasks for students.

Based on these guidelines, the science teachers started to plan their fifth intervention, examined in this study. In this intervention, the teachers chose to approach science careers through inquiry-based life-cycle assessment [35] and through the general aims of the MultiCO project [2]. The intervention was also planned to support the educational aims of the EU [45] and the Finnish national core curriculum [46]. The intervention in two different classes (32 students in total) was planned to last six lessons, 45 minutes each. The intervention was divided into three phases—(i) introduction and preconceptions, including the introduction of the career-based scenario, (ii) inquiry, and (iii) presentations, as presented below.

2.2.1. Phase 1: Introduction and Preconceptions

The intervention started by showing students short videos about the food industry and presenting them with industry-related careers. To increase individual relevance, the students discussed the different type of products they use in their everyday lives. After that, the teachers divided the students into groups of 2–3 students and gave them the task of choosing a product and examining its lifecycle. To increase societal and vocational relevance, the students were also required to interview someone working with the product during its lifecycle (the career-based scenario). The groups were free to choose a topic of their interest from a predetermined list of industries. The pre-determined industries were the plastic industry, cosmetics, the pharmaceutical industry, the paper industry, and the textiles industry.

As each industry manufactures many different types of products, each with unique life-cycles, the students were asked to choose one item from their chosen industry. The students were then asked to discuss and write down their preconceptions about the chosen product's life-cycle using the following questions:

1. What are the raw materials needed for the product?
2. Where is the product manufactured?
3. What do you know about the process of manufacturing the product?
4. What occupations are related to the manufacturing process? (the career-based scenario continues)

These questions were selected because of their vocational and societal relevance. The introduction phase was planned to last for two lessons, 45 minutes each.

2.2.2. Phase 2: Inquiry

During the inquiry phase, students were asked to search for information regarding their chosen product's lifecycle, examine careers related to the product's lifecycle, chose an expert to interview, and plan and conduct an interview (the career-based scenario continues).

The students mostly worked independently within their group, the teacher giving support when needed. They used Office 365 to share their work with each other and the teacher. Based on their inquiry and interviews, the students were asked to make a presentation in which they consider the following issues:

- Explain the main features of the manufacturing process concerning chemistry;
- Describe the product's life cycle and define where it ends up after use;
- Present evidence about the environmental burden of the manufacturing process and about the consumption of the product;
- Find out what type of specialists are needed for the manufacturing the product;
- Interview a specialist from the industry.

The inquiry phase lasted for two lessons, and students continued to work on the projects after school as homework.

2.2.3. Phase 3: Presentations

In the last phase of the intervention, students presented their group work to each other. The presentations included drawings of their product's lifecycle and discussion on occupations related to the product's lifecycle. Students also revisited the interviews they conducted, presenting to the class what type of work the interviewee does. After the presentations, the teacher took a few minutes to make a summary about the strengths of the presentation. The teachers had emphasized that the projects, including the whole process, are a part of students' holistic evaluation, but in addition to the instructions mentioned above, more specific evaluation criteria were not given, as is common practice in Finland.

2.3. Data Collection and Analysis

The present study follows the convergent mixed methods case study design. This type of design has a strong qualitative orientation to research [47]. The methodology of this case study consists of qualitative and quantitative methods which is characteristic for this type of mixed methods study. The data was collected before, during and after the intervention through several methods to ensure reliability. The collected data sources are independent and were analyzed separately to help gain a more complete understanding of the case.

First, the lessons were observed by a researcher. To help the collection of data, researcher used observation sheets, which contained listed foregoing variables listed. A structured list of themes was created for the observation of the intervention. The observer wrote down notes about students' and teachers' interactions. The notes from the observations were analyzed by two researchers to examine how well the original lesson plan was implemented and whether any critical aspects were omitted regarding this study. The analysis showed that one of the teachers, Janet, carried out the lesson as described above. The other teacher, Sara, had less time available for the intervention, so she modified the plan so that, instead of the students interviewing experts, they watched videos about different industrial occupations.

Second, quantitative data was collected from the students at the end of the intervention. The questionnaire was developed for the MultiCO project and has been used and validated in previous studies [18,48]. To analyze the answers, questions were categorized into five main categories: (i) individual relevance, (ii) social relevance, (iii) vocational relevance (knowledge gain), (iv) vocational relevance (future aspiration), and (v) interest (adopted from reference [18]). Slight changes were made to the questionnaire as in previous studies it was used to evaluate only part of the first lesson (scenario), while in this study, it was used to evaluate the entire intervention.

Third, data was collected by interviewing the teachers after the intervention to understand the choices they made when planning the intervention. The interviews were semi-structured interviews containing open-ended questions on (1) creating a scenario and connecting it with science teaching;

(2) the interventions' impact on students' career and working life skills awareness; (3) students' relevance, engagement, and interests; and (4) linking science with society. Questions were flexible, allowing space for emerging questions and giving the researcher the opportunity to ask suitable follow-up questions (c.f. [49]). These retrospective interviews were transcribed and then analyzed using inductive content analysis. The analysis focused on teachers' reflection of their own and students' actions, as well as their perceptions about the intervention. The interview protocol was planned together with three researchers. One researcher conducted all of the interviews to ensure that they were all implemented in a similar way. Transcriptions and translations were crosschecked by two researchers and then analyzed by the first author. The analysis was then checked by another researcher to ensure that misinterpretations of the data were not made. In cases of disagreement, analysis was discussed by the researchers until both agreed on the interpretation of the data (c.f. [47]).

Fourth, the students were interviewed after the intervention to get more detailed information about how they relate with the intervention. Furthermore, the interviews focused on finding out the reasons behind students' interest in science learning in general. The interviews were analyzed using inductive and deductive content analysis [50] by two of the authors. To increase the validity of the analysis and to make sure that data was not taken out of context, the researchers analyzed and discussed the interviews together. Interpretations of the interviews were discussed until the researchers reached consensus.

Finally, the students' presentations on the products LCA were analyzed by two researchers using inductive and deductive content analysis. Inductive analysis was used to examine how the students present and talk about science related careers and environmental issues. Deductive content analysis was used to examine how students' presentations depict different dimensions of relevant education (c.f. [13]). Analysis was conducted by the first and second author in the same way as the student interviews, explained above. The methods are shown in Figure 1. After analyzing the quantitative and qualitative data, the results were integrated to interpret the case in-depth. The present study involves a complex design and combines various analyses. We propose a joint display and comparison discussion based on our results.

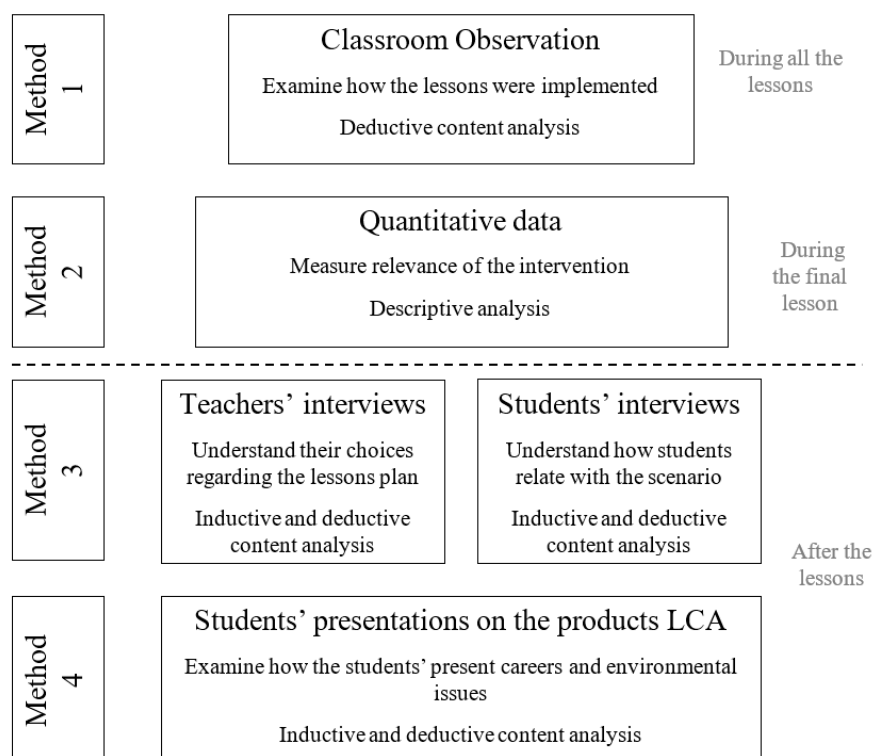


Figure 1. Data, methods, and aims of the study.

The results are presented in two main parts. First, we will introduce the descriptive analysis of the questionnaire. Second, the qualitative results of the interviews and students' presentations are presented. In addition, there are excerpts from observation notes to support the reliability of the research data.

3. Results

Table 1 shows the means and standard deviations of the items in the questionnaire. The items are divided into different categories, according to previous research [18]. According to the questionnaire the overall perception of the life-cycle assessment intervention was positive, the means varying from 2.84 to 3.28. Students felt that the intervention was easy to follow ($M = 3.28$) and understand ($M = 3.24$). They also liked the way the intervention was carried out ($M = 2.84$) (see Table 1).

Table 1. Evaluation of intervention by the students.

Category	Subcategory	Item	M (SD)
General perception		The intervention is easy to follow.	3.28 (0.54)
		The intervention is easy to understand.	3.24 (0.52)
		I like the format of the intervention.	2.84 (0.47)
Relevance	Individual dimension	This intervention enables me to gain new knowledge about the topic (life-cycle assessment).	3.16 (0.75)
		The knowledge I gain from the intervention may be useful in the future.	2.96 (0.35)
		I can put knowledge gained from the intervention into practice, to solve problems.	2.56 (0.71)
		I find this intervention topic important for me personally.	2.52 (0.77)
		I find this intervention topic important to my family.	2.60 (0.58)
		I find this intervention topic important for learning school subjects.	2.54 (0.83)
	Social dimension	I find this intervention topic important for appreciating the work of our local community (town, country).	2.60 (0.76)
		I find this intervention topic important for the whole world.	3.32 (0.85)
		The intervention presents a scientific problem, which is socially relevant.	2.88 (1.01)
	Vocational dimension (knowledge gain)	From this intervention, I am able to gain new knowledge about possible career(s).	2.56 (0.65)
		This intervention enables me to understand the responsibilities of the persons in the career position indicated.	2.48 (0.59)
		This intervention enables me to understand the skills that are necessary in this profession.	2.28 (0.68)
	Vocational dimension (future aspiration)	I feel my future career may be connected with the topic covered in the intervention.	1.96 (0.75)
		I think my future studies at the gymnasium or university level may be connected to the topic covered in the intervention.	2.08 (0.81)
		I predict I will need to perform skills, described in the intervention, in my future career.	2.08 (0.64)
		I predict I need to perform science-related skills, described in the intervention, in my future career.	2.20 (0.65)
		The intervention describes the science community, to which I relate.	2.16 (0.75)

Note. M = Mean, SD = Standard deviation.

3.1. Descriptive Analysis of the Relevance Subcategories

The individual relevance item means varied from 2.52 to 3.16. Furthermore, the students felt that they gained new knowledge ($M = 3.16$) and that this knowledge may be useful to them in the future ($M = 2.96$). The students also perceived that the topic was somewhat important for them personally ($M = 2.52$), to family ($M = 2.60$), and for learning school subjects ($M = 2.54$). They also felt that they can use the experience gained in practice ($M = 2.56$) to solve problems.

The lowest social relevance item mean was 2.60, and the highest was 3.32. The students found the intervention to be socially relevant, as they understood that they were dealing with a topic that was important to the whole world ($M = 3.32$) and that the problem was scientifically relevant ($M = 2.88$).

The topic was perceived as somewhat important for appreciating the work of local community ($M = 2.60$).

The vocational relevance items had the lowest mean scores, varying from 1.96 to 2.56. The questionnaire and student interviews show that the vocational relevance was two-fold. On the one hand, the students perceived the intervention to help them gain knowledge about possible careers ($M = 2.56$) and the responsibilities involved in these careers ($M = 2.48$). On the other hand, the students did not feel that the acquired skills and knowledge will be useful in their future careers or that their future careers will be related to the topic ($M = 1.96$).

3.2. Qualitative Results of Relevance Subcategories

The qualitative assessment of the relevance subcategories is presented in the following subsections.

3.2.1. Qualitative Assessment of Individual Relevance

Based on observations and teacher interviews, the students seemed to enjoy the freedom they were given with the task and there were only a few students who tried to avoid the given tasks.

The teachers were pleased about the students' presentations they help at the end of the intervention and particularly the level of new knowledge they presented.

In the teachers' interviews, Janet said,

"The students' presentations were impressive . . . It was one of the assignments to be evaluated. Even the students themselves said that it is a good way to do it (referring to evaluating the presentations)."

In the student interviews, several students pointed out that the reason why they enjoyed the intervention was because they enjoyed working in groups and because the tasks were different than what they were used to. For instance, Susanne said,

"This intervention has increased my interest because] we got to do many different types of things. It increases my interest that we don't just sit in class and do tasks . . . we had group work and such. So, this has increased my interest."

Maria seemed to agree:

"I think everything was done nicely and it was easy and fun to work. The tasks were different. For instance, we all got to present our work and we could see different ways on how the things can be presented."

The students' original citations indicate that they were curious and interested. The students point out that the diverse working methods during the intervention were individually significant.

3.2.2. Qualitative Assessment of Social Relevance

According to the observation notes, some of the students were concerned about their everyday life choices and how their actions will impact the environment. Furthermore, their teacher pointed out in the interview that students brought up environmental issues and values and they were very well aware about the products' lifecycles. Sara said,

"The students had found in this last (intervention), as they did the interviews themselves, and where they found quite well the information and knowledge. It left me . . . Well it was touching, for me. I mean that those young people told that values like this have risen, for example, in forest industries. That these things are thought about anyway.

"And they (drawings on the products' lifecycles) were so impressive, how they imagined the manufacturing. I was surprised they were so complete even though they did not get any sources of information other than their own mind."

The student interviews and presentations indicate that the environmental aspects in lifecycle assessment played a key role in making the intervention socially relevant. Several students pointed out these environmental issues in their interviews. For example, Caitlin said,

“The products’ lifecycles dealt with many environmental issues. For example, we found out how much water a pair of jeans needs and so forth.”

Some students also reflected on their personal lifestyle, realizing that they want to change their habits. In the student interview, Jamie said,

“We used to all be somewhat reckless in how we disposed plastic, but in the future, we want to pay more attention to this, because making the presentation really got us thinking (about these issues).”

Similarly, environmental issues were tied to social issues in the students’ presentations. A plastic industry group of students from Janet’s class presented that,

“Human actions can cause direct plastic problems to the environment. Plastic dumped into oceans and our surroundings can harm animals. For instance, consumed plastic has been found in the stomach of dead birds. Also, water animals, such as fish and turtles have died because they have been trapped in plastic in the water. After use, plastic must be disposed properly and not be left into the nature.”

The realization of the existing environmental problems resulted in at least some of the students advocating a more sustainable lifestyle. For instance, the students belonging to a group that did their lifecycle assessment of the textile industry said,

“It is better to buy local products, because then you support local companies ... clothes produced in far-away countries (especially in Asia and Africa) have ‘hidden water,’ and the workers may work under bad working conditions and may even use child-labor. Also, the transportation of materials pollutes the environment.”

The students’ presentations implemented promotion of their own interest in social discourse and the content includes global concerns about their consumer choices.

3.2.3. Qualitative Assessment of Vocational Relevance

Based on classroom observations and teacher interviews, students seemed to have a general interest towards learning more about science careers involved around LCA. The teacher interviews showed that the teachers were surprised but appreciative of the way students gathered information about the careers related to the products lifecycle and how the students discussed career-related ethical and sustainability issues. According to Janet, the students had not thought that such values would present themselves in the science-related careers:

“I felt that when the students learned about the different careers, environmental values arose: How environmental issues are present in the careers? It seems that during this ninth schoolyear it has become an important value for the students to be involved in environmental issues. They hadn’t thought that environmental issues would come up in the careers.”

Furthermore, in their presentations, Janet’s students seemed to find it important to describe how careers were related to environmental aspects. For instance, the student group that interviewed an expert working in the paper industry highlighted the following quote in their presentation:

“I didn’t really know anything about this sector when I started work here five years ago. I was interested in this job because it allows me to work on things that will enable the world to have more recyclable and biodegradable products to replace plastic and other fossil-fuel based products. Our company is a producer of biodegradable products (not just paper) and we think that someday, for example, plastic bottles can be replaced by a product that can be recycled. We constantly work to make this happen.”

In the students’ interviews, they indicated that it was interesting to learn about different careers but that they were not personally interested in these careers. This was especially apparent in the interview with Tim:

R: “Are you interested (in a career) in the type of jobs you learned about, or their daily tasks?”

T: “Well, I didn’t gain much interest in them (as a career), but it was still interesting to hear about them and know what different jobs are like.”

Similarly, Susan indicated a general interest but was unsure whether she would be interested in an LCA related career for herself:

R: “During the project, have you gained new knowledge about careers related to science?”

S: “Well, yes, because I didn’t know that so many people work in this kind of jobs. I never really thought about it before, that there is this kind of people who do this kind of job.”

R: “So, did your interest in this type of jobs increase?”

S: “Well, they were quite interesting, but I don’t know about going into those fields myself. But ya, they were interesting, and they got me thinking about things. About what is available.”

3.3. Merging Descriptive Analysis and Qualitative Assessment

Individual relevance. According to the students’ questionnaire responses and teachers’ interviews, the students gained new knowledge, and the teachers were satisfied about the knowledge the students achieved. The students told that working in groups and the novelty of the tasks were reasons for their efforts. However, the students saw the new gained knowledge to have only slight personal importance ($M = 2.52$). Also, the original citations suggest that individual relevance was not reached by the topic used in LCA.

Social relevance. The student interviews and the questionnaire responses both pointed out that the students understood that the topic was globally important and that especially the environmental aspects in LCA made the intervention socially relevant. Also, the students’ output showed that they are interested in their consumer choices that could cause environmental problems. Furthermore, the lessons seemed to initiate processes where the students’ realized how they can take actions to avoid reckless behavior. The teachers’ interviews also confirmed the global importance of the lessons.

Vocational relevance. The means to the questionnaire item regarding future aspirations of vocational dimension varied from 1.96 to 2.20, which can be interpreted to be partly negative. This is in line with the students’ interviews where they stated general interest but did not see the presented science careers significant for themselves. In the questionnaire, the students somewhat agreed that they gained new knowledge about the responsibilities involved in these careers ($M = 2.48$). This was also apparent in the teachers’ interviews.

4. Discussion

This study examined how implementing life-cycle assessment as a context could help make science education relevant on an individual, societal, and vocational level (cf. [5,16–18]). As most of the previous life cycle assessment studies have been implemented in higher education [16], this study,

conducted among ninth graders, gives new insight into using lifecycle assessment in lower secondary school science education. Using LCA as a context and the structure used in the intervention, seem to be an appropriate way to study science and particularly present scientific careers in a real-life context to students (c.f. [19,22]).

4.1. Individual Relevance

The results of this study show that using LCA as a context in lower secondary school can increase individual relevance of science education. In this study, individual relevance seemed to be caused by several aspects. Some of these aspects were not necessarily connected to life-cycle assessment per se, but rather, the general structure of the lessons. For instance, previous studies have shown that when a lesson has a close link to everyday life, students find it more relevant [5,7,19–21]. This was also the case in this study, as students examined products that they were familiar with. Furthermore, this study shows that individual relevance can be increased by allowing students to work in groups and by giving a range of different tasks to work on. However, in this study, individual relevance seemed to also be caused by the fact that students enjoyed analyzing a products lifecycle and interviewing experts. Students did not only report gaining new knowledge but also felt that this knowledge was useful to them both now and in the future [22]. This finding supports the notion that environmental topics can increase the individual relevance of science education and that lifecycle assessment is one means to do so. Furthermore, dealing with a product's lifecycle made students reflect on consumer behavior on an individual and societal level, potentially helping develop critical thinking skills and systems thinking. Such reflections can increase the intrinsic relevance of the lessons and contain a future perspective, as students need to examine what type of pro-environmental actions they can take (c.f. [5]).

4.2. Societal Relevance

The study also shows that using LCA as a context brings societal relevance to school science education. In this study, LCA offered an opportunity to deal with issues such as the environment, climate change, and health (c.f. [45]). Especially the expert interviews conducted by the students seemed to increase students' environmental knowledge and helped them see the strong link between LCA and society. Though previous studies indicate that 9th grade students are generally not too interested in environmental issues [38], this was not seen in how students felt about the societal relevance of LCA. This could be due to the fact that students are especially interested in societal and ethical aspects related to the environment [29,39], and LCA has a clear relation to such issues. The findings also show that, at least in an LCA context, societal relevance is strongly linked to individual relevance. This is in line with previous studies that have shown that students take pro-environmental actions both on individual and societal levels [13].

LCA could also be used as a multidisciplinary context to address societal issues at large. Although in this study, students primarily considered environmental issues, LCA could also be used to examine many other societal issues, such as working conditions, health of workers, and wages [27]. As students consider many ethical issues when dealing with environmental issues [39], a stronger socio-scientific approach to LCA could give students the opportunity to reflect on their individual and societies values and consumption habits. For instance, in the context of LCA, students could be guided to consider what type of values they uphold when they buy from producers who do not take care of the wellbeing of their workers and how they could change their consumption habits in order mitigate the societal impact of consumption choices. Such considerations would be most productive if done in collaboration with other subject teachers. Therefore, LCA is also a good context to practice multidisciplinary education and help develop students' systems thinking and critical thinking skills.

As students are keen to consider their role in society and what type of pro-environmental actions they want to undertake [13], linking societal aspects of LCA could also help increase individual relevance and vocational relevance. Such lesson structures support the educational aims of the EU [45] as well as the Finnish national core curriculum [46].

4.3. Vocational Relevance

Although teachers implemented aspects of vocational relevance by making a strong connection to working life and careers in the intervention, the students did not see the introduced careers as future opportunities for themselves. This shows how complex it is to determine what is vocationally relevant and to whom. One reason why there is a discrepancy in how teachers and students viewed vocational relevance could be because the development of career aspirations may be hard to realize in the present, as career aspirations typically are built over time and can be caused by the sum of many things (c.f. [5]). Teachers may believe that the career-related interventions may affect a student's career aspirations in the long-term, while a student may not be aware how their career aspirations may be caused by a number of little things that happen over a long period of time. Furthermore, teachers may have a better understanding how understanding certain issues, such as LCA may open up many career opportunities in the future, which is why they viewed the topic to have vocational relevance. Another reason may be that students mainly examined careers that were related to both LCA and science, not realizing that LCA can be useful in many other careers as well, to which their future career aspirations may be more closely linked (cf. [2–4]). Once a student has consciously decided not to choose a science-related career, they may find science education less relevant [5], which may also cause students to view LCA as less relevant to them, at least from a vocational perspective.

One reason for low vocational relevance (c.f. [32,34]) in this study could be that the students only familiarized themselves with one career in detail. Though they were able to decide which career to familiarize themselves with, they may not have been able to relate to the chosen career because of many reasons, including outside factors, such as the personality of the expert they interviewed. Although teachers planned for the students to familiarize themselves with several different occupations, this plan was not followed through extensively. Of course, the students did learn about other careers through their classmate's presentations, but the depth of these was much narrower than what they learned through their own interviews. Vocational relevance could possibly be increased if students could familiarize themselves with several occupations in depth. However, another problem in finding vocational relevance in the intervention could be with transferability of knowledge, meaning that students did not see the direct benefit of what they learned about the careers. One reason for these challenges could be that not enough time was spent discussing different careers or that the discussion came too late in the students' lives. Such an idea of "too little, too late" has been proposed in previous studies [51] and suggests that career opportunities need to be discussed extensively already with younger students.

The qualitative data shows that students learned about career opportunities and that they found it interesting to learn about different careers. However, the quantitative data in this study indicates that vocational relevance to the students was scarce. This controversy could mean that the intervention may not directly affect students' own career aspirations, but it may help them understand the diversity of careers where science is needed, and therefore, learn to appreciate the importance of science on a general level. This could lead them to choose science studies in upper secondary school level more than expected [1]. Moreover, understanding on LCA and the work of scientists is a way to increase citizenship education [13]. To increase interest toward science-related careers, it may also be useful to make students aware of some of the benefits of "white collar" jobs (which science-related jobs typically are), such as more flexible working hours, potentially better salaries, and abundant opportunities to work in many corners of the world. Such external factors may also have an effect on vocational relevance [5].

Therefore, although this study did not indicate that experiences in LCA would promote students wanting to pursue green jobs, the vocational dimension of this intervention was still important. As researchers have noted [52], vocational relevance should not be viewed too narrowly as it can contain learning about (i) professional practice, (ii) science and technological applications, and (iii) career opportunities. In addition, vocational relevance can help students understand the diversity

of careers where science is needed and therefore learn to appreciate the importance of science on a general level.

5. Conclusions

Using LCA as a context brings individual, societal and vocational relevance to science education. The study shows that LCA offers the opportunity for students to see science in a real-life context and promotes discussion on ethics and moral issues, needed more in science education [29]. Students understand the importance of LCA to their life and especially to society.

However, although the LCA intervention presented in this study provides a good platform for introducing science related careers, the intervention did not have an effect on students' career goals. Individual and societal relevance also have room for improvement. Therefore, further studies are needed on how using LCA as a context can support relevant education and, especially, vocational relevance. Future interventions could potentially bring more vocational relevance to the students by connecting LCA to their already existing career aspirations. For instance, the students could be allowed to do a product's LCA on something they think they will need in their future careers. Such an approach could also bring individual relevance to the project. Such a "Scientific Literacy for All" [10,11] approach could also use LCA to help develop the students' scientific literacy and systems thinking skills while acknowledging that the student may not want to pursue a career in science or technology. Furthermore, as vocational relevance and career aspirations can often only be seen in the long-term, longitudinal studies are called for. Furthermore, in LCA, ethical, economical, and health-related issues should be more strongly present to combine individual, societal, and vocational relevance. For instance, in mathematics, students could calculate the cost structure of a product, including cost of potential environmental damage, and in geography class, students could examine a product's lifecycle from a global trade perspective. To help broaden students view on the importance of LCA as well as the relevance of the topic, LCA could be made a multidisciplinary project in which different subjects/teachers view product lifecycles from different perspectives.

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