Students' Reasoning About Sustainable Development in Relation to Products' Life Cycles

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ABSTRACT

In this study, we investigate Secondary School students' reasoning about products' life cycles in relation to three dimensions of sustainable development: economic, social, and ecological sustainable development. Production and consumption are part of a complex socio-technological system that affect nature and life on earth, and knowledge about this complex system are required to achieve sustainable development. In technology education, students can have the opportunity to reason about products and their life cycles. Hence, this study aims to explore what emerges in students' reasoning about products' life cycles in relation to sustainable development. Data collection was conducted in Sweden through two semi-structured interviews, with students participating in focus groups containing 3 and 4 participants in each group. All student responses have been analysed using thematic analysis to explore dimensions of sustainability. Results show that the students' reason with regard to all three dimensions of sustainable development. However, the three dimensions occur to varying extent within the different phases of a product's life cycle. Additionally, the students also connect dimensions in their reasoning, with both harmonious and contrasting perspectives. Participating students' reasoning indicated traces of an anthropocentric view. These results have implications for technology education, both related to content and practice, which is an important step towards education for sustainable development.

Key Words: Technology education, Sustainable development, Product life cycle, Reasoning

1. INTRODUCTION AND BACKGROUND

The interaction between production and consumption constitutes a complex socio-technological system that impacts the environment and the overall well-being of life on our planet. For production and consumption to be sustainable, consideration should be given to the entire life cycle of products (United Nations, 2015). Hence, products' life cycles are undeniably intertwined with sustainable development. Despite of the varying focus of perspectives in curricula around the world (Jones et al. 2013), this has implications for technology education where the product life cycle is included. Furthermore, sustainable development is considered an important part of

technology education (e.g., Elshof, 2009; Pavlova, 2009) where a holistic perspective with a pluralistic view highlighting the connections between economic, ecological, and social dimensions is desirable (Berglund & Gericke, 2016).

Concurrently, education in sustainable development presents a complexity rooted in the systemic structure of sustainability issues. Studies show that it is important to explore these tensions inherent in sustainability issues to enhance learning about the complexity of sustainable development and to develop skills such as systems thinking and critical thinking (Herremans & Reid, 2003; Sterneäng & Lundholm, 2012). In line with this, students' assignments were analysed by Öhman & Öhman's (2012) based on the social, ecological and economic dimensions. The results showed that the students referred to all three dimensions and also interrelated them. However, the study concluded that the students described these relationships as harmonious and did not identify conflicts of interest between the dimensions.

Additionally, there are different moral and philosophical views associated with the concept of sustainable development. With an anthropocentric view, humanity is at the centre, and nature's resources are there for humans to use. An alternative view, ecocentric, places nature at the centre, and humans are a part of the natural ecosystem (Dobson, 1996). Moreover, Pavlova (2009) proposes that weak anthropocentrism, which promotes the mutual thriving of human and non-human nature, is suitable for education in sustainable development within technology education.

1.1. Aim and Research Questions

In technology education, students have the opportunity to engage in reasoning about products and their life cycles. Gaining knowledge about students' reasoning in relation to sustainable development is important for practitioners within technology education, as well as for further research. However, limited research has been conducted regarding this. Hence, our aim is to investigate what students reason about in relation to sustainable development, guided by the following research questions.

1.1.1. Research questions

(i) What emerges in students' reasoning about the life cycles of products in relation to the social, ecological, and economic dimensions of sustainable development?

(ii) How are these dimensions connected in the students' reasoning?

2. THEORETICAL FRAMEWORK

In this study, Toulmin's Argument Pattern, as described by Erduran et al. (2004), was used as a theoretical framework for students' reasoning. Previously, it has been used as an analysing tool in studies to frame students' individual, as well as collective, reasoning (Erduran et al.). In Toulmin's Argument Pattern, reasoning consists of a *claim* that is supported by relevant *data* and that *warrants* establishing a connection between the data and the claim. To concretize or

strengthen the warrants a *backing* can be made. Additionally, the reasoning can consist of *rebuttals* that identify specific circumstances in which the claim would not remain valid.

To theoretically frame sustainable development, the United Nations Commission for Sustainable Development (CSD report, 2001) was used, where sustainable development contains environmental, social and economic dimensions. The framework was developed to form indicators for corporate social responsibility, and it states factors for each dimension. For the social dimension, the themes are equity, health, education, housing, and security. For the environmental dimension the factors are atmosphere, land, oceans, seas and coasts, fresh water, and biodiversity. While for the economic dimension, they are consumption and production patterns and economic structure.

The product life cycle can consist of different phases. In this study, we view this life cycle as consisting of four phases: Production, transportation, usage & maintenance, and disposal. This has been adapted from the phases used by Vaesen (2012) with modifications to be relevant in the context of technology education.

3. METHOD

3.1. Data collection

To obtain a rich dataset of students' descriptions (Robson & McCartan, 2016), data were collected through two semi-structured interviews, where ninth-grade students (15-16 years old) participated in focus groups of 3 and 4 participants at two different schools in Sweden. Focus groups were chosen because students' reasoning can be enhanced when they are stimulated by each other's thoughts and comments (Robson & McCartan). Open questions related to the product life cycle were asked, with follow-up questions when the students' answers needed elaboration. For example, the question used to prompt reasoning about production was: "What do you know about the production of things like clothes and footballs, or mobile phones?". The interviews were audio recorded and subsequently transcribed manually.

3.2. Data analysis

The data was later analysed through thematic analysis, as described by Braun and Clarke (2006). During the analysis process, the authors adopted an interpretive approach regarding what the students were expressing (Braun & Clarke). From the theoretical framework, a code-scheme was established (Table 1). The transcripts were read and reread, and an initial coding of the data was performed separately by both authors using the code scheme. The coding was then discussed, and any uncertainties in the coding were resolved.

Table 1.
The code scheme used in the thematic analyses.

Sustainable development	Product life cycle
Social dimension	Production
Ecological dimension	Transportation
Economical dimension	Usage & Maintenace
	Disposal

Afterward, sections that were deemed relevant to the research questions and where the students were regarded to be reasoning following Toulmin's Argument Pattern, as described in section 2, were selected for further analysis. A second, repeated deductive coding of the relevant sections was conducted jointly by both authors using the code scheme described in Table 1, combined with inductive coding. Themes were then formed connected to each dimension of sustainable development and to each phase of the product life cycle. In a subsequent stage, themes were formed inductively to answer research question (ii). These themes were evaluated, and through discussion between the authors, the themes were refined to have clearer distinctions from each other.

4. RESULTS

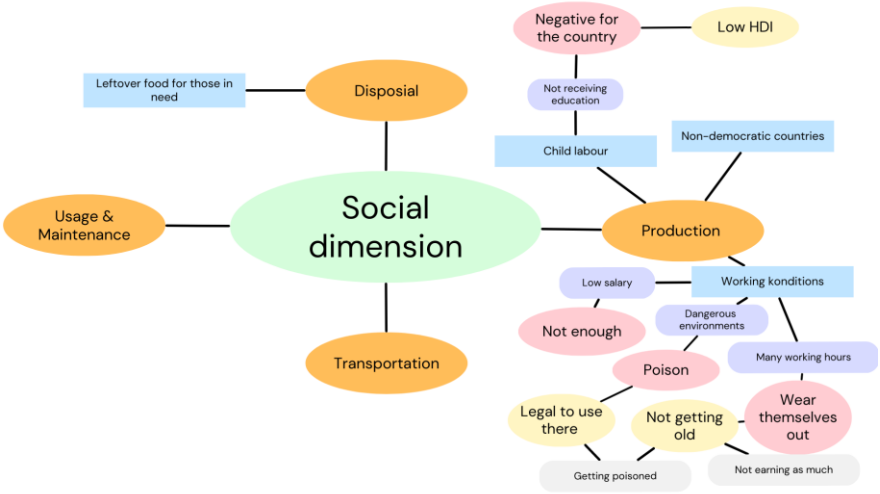
4.1. What emerges in students' reasoning about the life cycles of products in relation to the social, ecological, and economic dimensions of sustainable development?

The participation students mainly reason from the social dimension when considering the production of goods. However, when students reason about transportation and disposal, the ecological dimension becomes notably prominent. The economic dimension is predominantly evident when these students' reason about consumption and transportation.

4.1.1. The Social Dimension

The students' reasoning is primarily centered on the social dimension when they consider the production of goods (see Fig 1). In the production phase, both groups focus on the clothing industry, specifically the cotton industry. They claim that production is situated in other countries like Bangladesh, China, and Vietnam. Both groups' reasoning reveals that this production industry features poor working conditions, child labour, and takes place in countries that, in some cases, are not democracies (see Fig.1).

Fig 1.
Illustration of what emerges in the students' reasoning about products' life cycles in relation to the social dimension



Excerpt A shows students reasoning about working conditions and child labour. Alice reasons that the workers do not manage financially on their salaries, work long hours, and wear themselves out, which affects their health, and in the long run, their life expectancy and total lifetime income. The students' reasoning also reveals that the workers in this production are exposed to poison. Alex claims that these dangerous substances cause poor health and premature death. When the students reason that there is a lot of child labour, they do so in relation to the children's opportunity for education. Jane says that the Human Development Index (HDI) of these countries is low, but it would increase if the children were educated instead of having to work.

Excerpt A

Alice	But it's not only child labour, it's working conditions in general with long hours and low pay. They wear themselves out until ... so they don't get very old, so they don't have the energy left to work when they get older, which means that they can't earn as much money and they can't live on what they earn because the salary is far too low.
Alex	In many cases it is also ... it can be really dangerous environments they work in. Poisons and so on are very often used, and it is permitted in many countries to use life-threatening pesticides and so on, where many people die or are seriously injured.
Jane	But in the cotton industry, this happens every year and many people are poisoned, but another problem with child labour is that it is negative for the

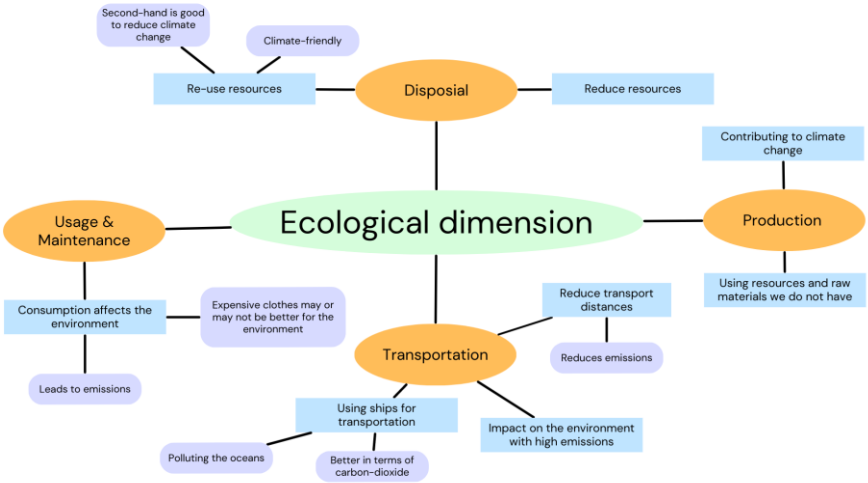
	country in the end because they are not educated, so they can't help move society forward, that's what I was going to say. So what is it called? Their D..i..
Nina	HDI
Jane	Yes, their HDI is low, and it could be raised if the focus was on educating children for just one more year.

The social dimension is absent in the student groups' reasoning about transportation and usage & maintenance. In their reasoning about disposal, the social dimension briefly appears when they reason that unused food raw materials can be prepared and given to people in need.

4.1.2. The Ecological Dimension

The ecological dimension stands out particularly when the students reason about transportation and disposal. The students reason about what they consider to be a good way of transporting goods based on its environmental impact. The reasoning reveal that transportation affects the environment due to its high emissions, the common use of ships, and the potential emissions reduction if distances could be decreased (see Fig. 2).

Fig 2.
Illustration of what emerges in the students' reasoning about products' life cycles in relation to the ecological dimension



Alice claims that boats are better than airplanes "in terms of carbon dioxide". However, in the same sentence, Alice also mentions that using boats is negative due to sea pollution. Likewise,

Jane argues that transport distances are "unnecessary", and if these could be reduced, emissions would decrease (see Excerpt B).

Excerpt B

Jane	I think many people have also started using boats, which is better, if you think in terms of carbon dioxide. But then it pollutes a lot of our oceans, so that's the negative.

In connection with disposal, several students state that raw materials and resources can be reused, leading to a reduction in our consumption of them. Student Alex also claims that recycling is beneficial for reducing climate change and links it to the substantial production of goods, which currently contributes to climate change. Thus, Alex states, it would be advantageous if we could increase reuse.

The ecological dimension also appears in connection with the consumption of goods, where the students mention the environmental impact of consumption. They also reason about the distinction between online purchases and in-store purchases, both of which are acknowledged to impact the environment and result in emissions. However, Noa suggests that more expensive goods can be better for the environment than cheap ones, whereas David counters that this is not necessarily true; you might just be paying for the label (see Excerpt C).

Excerpt C

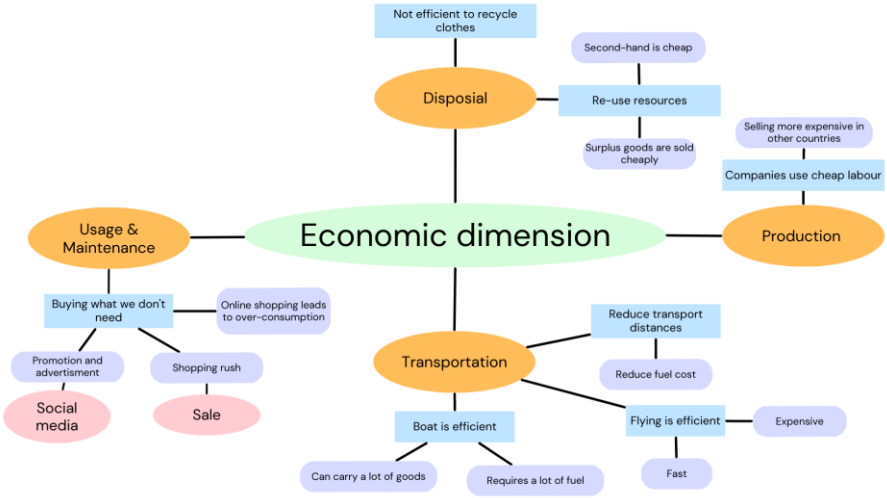
Noa	*Yes, and the goods that are better for the environment are usually more expensive. And then you have to think, should I pay more for the same product and be a little better or should I take cheaper products that are worse for the environment, but then people usually start to think that the environment is not affected, or this choice does not affect - although it might.*
David	*Then ... we can also ... that's .... Yes. The fact that it's more expensive doesn't always mean that it's better for the environment - you can also just pay for the label.*

Among the students, the terms 'carbon footprint', 'climate-smart', and 'helping the environment' are not further defined or explained. The concept of emissions is not exemplified. Nor does their reasoning explain why high fuel consumption and long, unnecessary journeys are considered negative.

4.1.3. The Economic Dimension

The economic dimension is predominately evident in the students' reasoning about usage & maintenance and transportation (see Fig. 3). They reason that we buy more than we need due to buying frenzies, which are reinforced by recurring sales such as Black Friday, Single Monday, and Cyber Monday. Additionally, they note that there are constant new trends and a lot of marketing (on social media) that unconsciously influences us to buy more.

Fig 3. Illustration of what emerges in the students' reasoning about products' life cycles in relation to the economic dimension



The students emphasise that the buying frenzy leads to mass production, which requires more resources and raw materials than we have and need (see Excerpt D for example).

Excerpt D

Alice	*You are sort of attracted in everything you do, as soon as you walk out the door you see adverts. Your head is always set on buying new things, which means that mass production becomes extreme and then you use resources and raw materials that you may not really have or need.*

Regarding transportation, the students mention that boats and airplanes are the two most common modes of transport. They reason that both boats and airplanes are efficient but possess their own advantages and disadvantages. Flights are fast but come at high cost. Boats, on the other hand, are noted by the students to be time-consuming and fuel-intensive, yet capable of transporting large quantities of goods and being more environmentally friendly "in terms of carbon dioxide". Jane suggests how the transport route could be made more efficient to reduce unnecessary long journeys. She explains that cotton is grown in one place, processed in another place, and then warehouses and shops are located at further distances from each other. She points out that cotton cannot be grown in Sweden, but processing could occur near the cotton farms, with each country having its own warehouse. She reasons that her proposal would reduce transport, which not only results in lower costs and emissions but also saves time.

In the production phase, the students reason that companies use cheap labour to be able to produce cheaply and then sell more expensively in other countries. Alice says that profits can be brought back into the business to increase the productivity and efficiency of the farms, which means that they earn more money for the country. In the end, she claims, the people who work there can also earn more and have better conditions. The economic dimension linked to disposal arose when the conversation shifted to the resale of goods, and the students' reason that surplus food and second-hand items can be sold at lower prices.

4.2. How are these dimensions connected in the students' reasoning?

The results show that when the students reason about products' life cycles they express connections to each dimension of sustainable development. However, they also establish connections between the dimensions, and the inductive analysis resulted in three themes: The Dimensions are Isolated, The Dimensions Harmonise and The Dimensions are Contrasted.

4.2.1. The Dimensions are Isolated

Within the students' reasoning, the dimensions occasionally occur isolated from each other, meaning that the students only reason from one perspective of sustainable development. This is particularly prominent when they reason about the social dimension in relation to production. During such instances, their reasoning is characterized by a lack of rebuttals and connections to the ecological or economic dimensions. In Excerpt E, the students Nina and Alex can be seen reasoning about poison and working conditions.

Excerpt E

Nina	There are also a number of toxins in the production process. and the workers get sick from it and don't get the best care, so it's kind of horrible.
Alex	*In many cases it is also ... well, it can be really dangerous environments they work in. Poisons and so on are very often used and it is permitted in many countries to use life-threatening pesticides and so on, where many die or are seriously injured.*

Within this reasoning (Excerpt E), they emphasise that issues related to workers' health arise when companies use poison in their production. These are aspects related to the social dimension of sustainable development. However, they do not establish connections to, for example, the ecological dimension and how the same poison affects ecosystems. This is characteristic of the students' reasoning, where the social dimension is rarely linked in any way to the ecological dimension.

4.2.2. The Dimensions Harmonise

The students express that the economic and ecological dimensions harmonise when they reason in connection with transportation and disposal. When reasoning about transportation, Jane states that shortening the transportation distances would decrease emissions and simultaneously lower the costs of fuel (see Excerpt F).

Excerpt F

Jane	*These are very unnecessary transport distances, and it would be possible to eliminate many thousands of kilometres and thus reduce emissions, simply by reorganising a little, and everyone would benefit in the long run because there would be lower fuel costs.*

Furthermore, when they reason about disposal, they do so with regard to the same dimensions, economic and ecological. They express that reusing resources, such as buying second-hand or utilising food waste, is both cost-effective and climate friendly.

4.2.3. The Dimensions are Contrasted

The dimensions are primarily contrasted when the students' reason about production and usage & maintenance. The economic and social dimensions are contrasted when they reason about production and companies' economic growth. The students state that companies use inexpensive labour with poor working conditions and child labour to promote economic growth. When reasoning about usage & maintenance, the students contrast the economic dimensions in terms of purchasing cheap or expensive products and relate this to the ecological dimension. They do this by reasoning about making compromises on the ecological dimensions to purchase cheaper products.

5. DISCUSSION

The sustainability dimensions manifest to varying degrees in the students' reasoning about different phases of a product's life cycle. In connection with the social dimension, they predominately reason from the perspective of workers during the production phase. However, the students do not reason about working conditions or child labour in any of the other phases of a product's life cycle. Here, the students reasoned thoroughly, but the same depth is not evident in the other dimensions. For example, in the ecological dimension, terms like "emissions" and "unfriendly to the environment" were not elaborated further. This may indicate that the students have more knowledge about production linked to the social dimension or that they consider this important and want to make visible. Another reason for the reasoning about other dimensions are less specific is that there might be unspoken truths so that the students do not feel the need explain further.

Öhman & Öhman (2012) showed in their study that students seldom reason about conflicts of interest and that the dimensions tend to harmonise with each other. The students in this study also reason about how the dimensions harmonise with each other but also that conflicts of interest can arise between them. This mirrors the relationship between sustainable development and the product life cycle which is full of contradictory objectives. Berglund and Gericke (2016) stress that the connections between the dimensions, whether harmonising or not, should be emphasised in education for sustainable development.

The students in this study reason deeply regarding the social dimension linked to production, yet connections are absent when they reason in relation to the ecological dimension. In both student

groups, they reason solely with the focus from the human perspective. For instance, it is mentioned that poison is released during production, impacting human health; however, no connections are drawn to the ecosystems as a whole and how plants and other animals also can be affected by the poison. Hence, traces of an anthropocentric view can be inferred from these students' reasoning. On this matter, Pavlova (2009) asserts that a weak anthropocentrism, where nature and humans mutually thrive, would be a desirable direction for technology education in the pursuit of achieving sustainable development.

These results have implications for technology education, both related to content and practice. Practitioners can utilise the knowledge and insights into how students might reason about sustainable development and product life cycles to plan and develop technology education. Simultaneously, these results serve as a foundation for further research in the pursuit and exploration of technology education for sustainable development.

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