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Developing design literacy for sustainability

Lower secondary students' life cycle thinking on their craft-based design products

Abstract
This article discusses the case study Case Keramikk, examining students' use of experiential learning from a craft-based design practice in life cycle thinking on their products. Data were constructed through semi-structured group interviews with students of a Norwegian lower secondary school and thematic analysis based on the principles and practices of design for sustainability (DfS). The interview questions engaged the students to assess their practice and products and to estimate environmental considerations. The students used experiential learning that correspond with the DfS practices of eco-efficiency, eco-effectiveness and product durability in the production phase, as well as the distinctive characteristics of materials, products and production decisive for practice of these in the material extraction and use and disposal phases. These reflections enhance students' development of design literacy for sustainability and strengthen their democratic participation in research for development of education in craft-based design for sustainability.

***Keywords*:** Design literacy for sustainability, design for sustainability (DfS), crafts-based DfS, lower secondary education

Inquiry in life cycle thinking within youths' craft-based design education

This article discusses the case study Case Keramikk, on students' use of experiences from craft-based design practice in their reflections on environmental considerations throughout their products' life cycle. The case study draws upon research concerning students' development of design literacy, which is a competence to understand and create design in physical materials in the context of what supports sustainable environments (Nielsen & Brænne, 2013). Furthermore, it draws on research that interprets and discusses the possibility for youths to develop qualifications for democratic participation in sustainable development and consumption through experience and reflection in design and crafts practice (Digranes & Fauske, 2010; Illeris, 2012; Lutnæs, 2015a, 2015b, 2017, 2018, In press; Lutnæs & Fallingen, 2017; Nielsen, 2009; Nielsen & Digranes, 2007, 2012). However, there is a need for empirical studies on students' experiential learning (Nielsen & Digranes, 2012).

I present an extensive data analysis of the experiences from creation of a craft-based design product that students use when asked to reflect on their practices, their products' quality and environmental considerations. Also, I address the kinds of environmentally considerate design practices, or design for sustainability (DfS) practices in product innovation (Ceschin & Gaziulusoy, 2016), that correspond with the students' experiences and therefore may be exemplified in their work. The concept of life cycle thinking (LCT; Heiskanen, 2002) is used to understand reflections on products' life cycles, from material extraction to product disposal. The results of my analysis raise epistemological questions concerning the potential for and relevance of students' development of design literacy for sustainability through embedding of LCT and DfS practices in their craft-based design practices. I discuss these questions in the context of knowledge theory by Klafki (1959/2001, 1985/2001).

Case Keramikk, semi-structured group interviews and thematic analysis

The case study, Case Keramikk, included seven 15–16-year-old students, two males (called Tom and Jon in this paper for anonymity) and five females (called Mia, Ann, Eva, Ada and Ane) who accepted my interview invitation. They were attending 10th grade, the last year of their compulsory education, at a Norwegian lower secondary school in the spring of 2015, and they had been tasked with a craft-based design project using clay in the school subject Art and Crafts. The research was performed with the consent of the students and their parents and the approval of Norwegian Centre for Research Data (NSD).

This case was theoretically sampled based on Nielsen and Brænne's (2013) description of the development of design literacy, for the clay projects' involvement of thorough, time-consuming craft-based design practices. The course was led by a teacher with subject specialisation in Art and Crafts and was held at a studio at the school. The students worked on the project over 18 three-hour lessons (altogether, 54 hours of the total of 146 hours Art and Crafts classes at the lower secondary level). Students were tasked with designing and crafting a utility object or sculpture and making a PowerPoint presentation of the process and product. The learning objectives included sketching designs and decoration and high-quality crafting of a utility object or sketching and interpreting the human figure in a sculpture. Five students (Mia, Ann, Tom, Eva and Ane) made vessels (approximate height 20–40 cm) with glazed decoration, while two (Ada and Jon) made sculptures of a human figure. The environmental context of their craft-based design products was not discussed during the project.

Semi-structured group interviews (Fontana & Frey, 2008; Kvale & Brinkmann, 2015) were conducted in two groups: interview group 1 (IG1), which comprised two students, and interview group 2 (IG2), which comprised five students. The interviews were held at the school, with the ceramic products present, and were documented with video recordings totalling 58 minutes for IG1 and 70 minutes for IG2. The interview questions, which included prepared questions with open-ended answers as well as improvised questions for elaboration or confirmation, asked about the environmental considerations in their ceramic products' design, production and use of materials. The questions were based on the DfS principles of LCT concerning raw material extraction, manufacturing, distribution, use and disposal (Cooper, 2005; Heiskanen, 2002) and triple bottom line (TBL) concerning aims of environmental sustainability with environmental quality, social equality and economic prosperity (Elkington, 1999). Moreover, DfS practices for eco-efficiency with low use of resources cradle-to-grave (Cooper, 2005, 2010), eco-effectiveness with circular use of resources cradle-to-cradle (McDonough and Braungart, 2009, 2013) and product durability and longevity (Chapman, 2009, 2010, 2015; Cooper, 2005, 2010; Stahel, 2010). The questions encouraged students to provide descriptions in their own terms rather than the technical vocabulary used in the selected theories.

A thematic analysis (King & Horrocks, 2010, pp. 142-174) of the interview video recordings was conducted in three stages with several steps. The first stage was *descriptive coding*. This involved familiarisation, transcription, tidying up of overlapping responses, anonymization of individuals with codes and organisation of the transcriptions in coded analytical units based on the introductory interview questions. The second stage was *interpretive coding*. Units were categorised into 3 themes based on the product life cycle phases of material extraction, production and use and disposal and 11 sub-themes regarding materials, products and production that correspond with DfS practices. The third step was *definition of overarching themes*. These themes were three DfS practices—eco-efficiency, eco-effectiveness and product durability—which relate to the experiential learning about materials, products and production mentioned by the students in their reflections on the life cycle phases (Figure 1).

DfS practices in the students' life cycle thinking about their craft-based design products

In collaboration with each other, the students used their experiences from the craft-based design practice in clay in reflections on the environmental context of their products' life cycle phases.

These include 1) material extraction, 2) production and 3) use and disposal. The thematic analysis shows that the students used experiential learning from the school studio that correspond with, and has potential as examples for engagement with:

a) *DfS practices in the production phase.* These practices include eco-efficiency with low use of resources; eco-effectiveness with circular, safe use of resources; and design for the durability of emotionally valuable personal belongings.
b) *Distinctive characteristics of materials, products and production decisive for DfS practices in the phases of material extraction and use and disposal.* These include eco-efficiency with low use of resources, eco-effectiveness with safe, circular use of resources and design for product durability through functional, emotional, aesthetic and intrinsic product qualities in decorative artefacts, personal belongings and gifts.

The data analysis reveals students' use of experiences and knowledge acquired during the production phase in their reflections on life cycle phases before and after the craft-based design practice. The extensive data document the students' subjective and contextual understandings of the craft-based design products they made at school. These are used to analyse the products' correspondence with—and relevance as examples of—different DfS practices and distinctive characteristics that determine whether or not DfS practices can be carried out. Figure 1 visualises the results in a model of LCT in craft-based design.

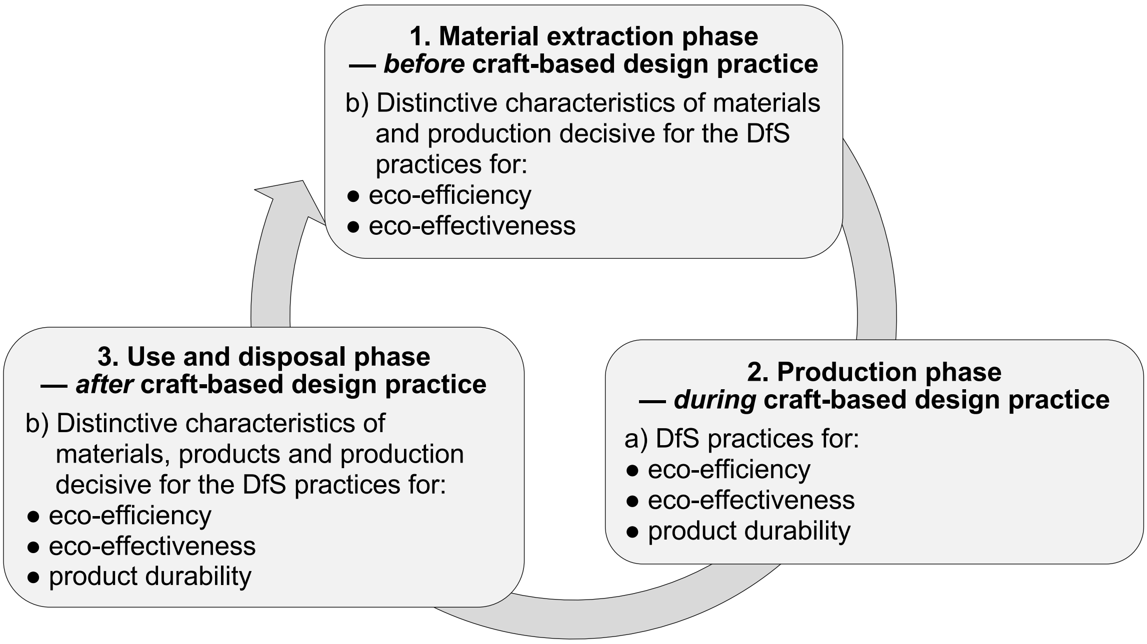

Figure 1. The model of LCT in craft-based design, containing the three life cycle phases of the students' craft-based design products and their experienced a) DfS practices and b) the distinctive characteristics of materials, products and production decisive for these practices.

In the interviews, the students described how they designed and crafted their products. They found inspiration in books (Tom, Eva, Jon) and on the Internet (Ann, Ane), and then they sketched the product they wanted to make. The five students who made vessels (Mia, Ann, Tom, Eva, Ane) also made a cardboard template of the intended profile to ensure accuracy and used a coiling technique and simple hand tools to make the vessels. Between classes, all the students wrapped their products to prevent them from drying (Ada, Jon, Ane). Finally, after firing, they created a mask with tape to guide application of glaze for decoration (Ane). The students agreed that the teacher's thorough guidance regarding the design and making processes was crucial for them to successfully make their products (Ann, Tom, Eva, Ada, Jon, Ane). One of the students said, "I learned how to do it. It would not have been possible without the teacher, because I would not have understood how to construct it by myself" (Ann).

Material extraction phase* — before *the craft-based design practice
The first phase (Figure 1) in the products' life cycle includes extraction and production of raw materials. This phase took place prior to the production phase of designing and making in the studio, and therefore was not experienced by the students.

Ecological resources for material extraction
Environmentally considerate practices of material extraction ensure that ecological resources are not depleted. The interview questions related to this topic asked the students about their knowledge of the clay's content, origin and renewal process as well as the environmental impact of extracting clay. In their reflections on the consequences of clay extraction, the students drew upon their knowledge about clay's distinctive characteristics and origin. In addition, they mentioned humans' use of clay throughout history. DfS theory emphasises eco-effectiveness that support circular use of resources including natural renewal processes (McDonough & Braungart, 2009, pp. 68-91). The students' reflections reveal how they estimated on whether clay is a renewable resource, or a non-renewable resource where the extraction for ceramic production exceed nature's development of new clay.

The students said that they had talked about the content of clay (Mia), but not read about it (Tom, Eva, Ada, Jon). They described clay as consisting of sand, gravel and water (Jon) or rock and soil (Mia). They believed that it was a naturally renewable resource but did not know how long the renewal process takes (Tom, Eva, Jon). One student thought that the renewal process of clay takes a long time (Ane), and two others stated that clay renews too slowly to keep up with demand and therefore will be depleted (Mia, Ann). One believed that it is likely there are negative consequences of excavating clay, as everything has negative consequences (Ada). In contrast, another student believed that it is unlikely that clay extraction has negative consequences, as humans have used clay since the Stone Age and thus the effects of clay extraction should have been observed by now (Jon).

Human resources in the process of material extraction
Environmentally considerate practices of material extraction must consider the human resources involved in this process; extraction workers must have social equality with living wages and acceptable working conditions. The interview questions concerned whether the clay had been extracted in Norway or another part of the world as well as what the students thought about the work conditions and wages for clay extraction workers and the price of clay. The students drew upon their experiences and knowledge of the clay's distinctive characteristics of weight, consistency and origin. DfS theory emphasises eco-efficiency, defined as productive use and reduced loss of material resources (i.e. raw material and energy; Cooper, 2005). The students referred to similar ideas regarding efficiency of the use of human resources when they estimated the working conditions and possibilities of using machines for material extraction to reduce the burden of extraction workers.

None of the students knew which part of the world the clay had come from, but one suggested that it is likely the package for the clay contains information about this (Jon). The students reasoned that extraction workers have a burdensome (Ann, Ada) and dirty job (Ada) but receive low wages (Mia, Ann, Ada). One stated that the use of machines probably makes extraction less burdensome for the workers (Mia). The students believed clay to be a cheap material (Mia, Ann, Ada), and that it was used in the class because they assumed the school's financial status was poor (Jon, Ane). Another student reasoned that different types of clay could have different prices (Eva).

Production phase* — during *the craft-based design practice

The production phase (Figure 1) in the products' life cycle involves safe and efficient use of material and human resources. The students experienced this phase while participating in the craft-based design practice at the school's studio.

Effective use of material resources

Environmentally considerate production practices ensure that material resources are not wasted. The interview questions concerned the students' experiences with the remains and squandering of materials as well as their opinions on relevant approaches for learning environmentally considerate practices as part of this project. The students used their experiences with efficient use of clay, effective recycling with reclaiming of dry clay shreds and inefficient use of clay in the crafting process. DfS theory emphasises eco-efficiency in terms of productive use and reduced loss of material resources during production (Cooper, 2005) and eco-effectiveness in terms of recycling disposed material resources (McDonough & Braungart, 2009, pp. 92-117). Among the students, squandering and ways to reduce it were topics of discussion. They highlighted the potential of learning for efficient use of resources and waste reduction during the production process.

The students explained that, while crafting their ceramic products, some clay was wasted because students threw clay around inside the studio (Mia), they took more clay out of the package than they needed (Ada) or they did not properly close the clay package, causing that the clay dried up and became unusable (Ann, Ada). The students confirmed that they tried to more completely close the package after experiencing that the clay became dry and hard (Ada, Jon). They had also learned how one can mix dry clay with water into a slip and use it to join different parts (Eva, Jon, Ane). One of the students said that they could have taken better care of the materials (Mia). Others suggested that reduction of squandering is one way to learn environmentally considerate practices (Ada), another is firing of clay (Mia), which is energy-consuming. Although one of the students said that the class had not talked much about the squandering of materials (Mia), believed another that the teacher wanted them to take care of the materials (Ann), while a third did not have the same impression of the teacher's opinion on the squandering because he had worked with a type of clay that neither the he nor the teacher considered suitable (Jon). The need to avoid squandering was explained by one as follows: "It wastes everything. It wastes money and material. There is no point in having something and just throwing it away" (Ann). However, reducing squandering is a difficult goal to achieve, admitted another: "I am interested, but it is not certain that one is engaged enough to actually do much, even though one thinks it is stupid how things are. It is stupid that we throw away so much, but one still throws away things" (Eva).

Health, environmental and security precautions

Environmentally considerate practices in production process must take health, environment and security (HES) precautions into account. The interview questions concerned the students' knowledge about the potential toxicity of the materials and their use of protection against the materials. The students explained their experiences with HES precautions during glazing. The DfS practices of eco-efficiency and eco-effectiveness emphasise reduction and substitution of materials that cause hazardous emissions and the need to design for and use materials that will be safe throughout the product's life cycle (Cooper, 2005; McDonough & Braungart, 2009, pp. 53-63). The students shared this emphasis, mentioning that they are aware of the need to use protective equipment to safely applied glaze. However, they experienced some inconveniences when using the equipment.

After modelling and firing their products, the students applied glaze, which was toxic during application (Ann, Eva, Ada, Jon, Ane). One student noted that it was important to avoid inhaling dust from the glaze while scraping the edges of the decoration (Ann). They wore gloves and particle masks for protection while working with certain types of glaze (Ann, Ada), but one student said that it was uncomfortable to wear the elastic band around her head and it was better to hold the mask in front of her mouth and nose, which was unpractical when both hands were needed to decorate the work (Ann).

Production and product value

Environmentally considerate production practice that offer social equality through living wages, depend upon the products' economic value. The interview questions regarding this issue concerned students' thoughts about a suitable price for their products and how this price relates to their production work, potential wages and material costs. The students drew upon their experiences with using their own human resources in the production process as well as their products' contextual meaning and value. DfS theory emphasises that objects with context-specific meaning and personal belongings are valued as emotionally durable objects that carry narratives and manifest memories (Chapman, 2010, p. 70, 2015, pp. 42-47). Estimating the relation between their products' potential prices and their work provided students an opportunity to reflect on potential wages. They considered their products to be of little economic value and not comparable to either manufactured retail products or professionally handmade products. Rather, the products are personal belongings with emotional value, as they narrate and manifest their experiences with the production process in the school context.

The students suggested that suitable prices for their products would be nothing (Jon), 50 Norwegian kroner (USD 6; Ann, Ane) or 100 kroner (USD 12; Mia, Ann). When asked how this price relates to their work in the production process, they estimated that they spent approximately 60 hours on the project (Eva, Jon, Ane; a more accurate estimate would be 54 hours, as they forgot to eliminate time for public holidays). The students said the clay work was time-consuming (Mia, Ann), with two describing it as more time-consuming and monotonous than they expected (Eva, Ane). They agreed that the prices they suggested were not likely to even cover the material expenses, so the hourly wage would be almost nothing (Mia, Ann, Jon). One student acknowledged that products made from large amounts of clay are worth more than smaller products (Ada). However, their experiences with their products related to their beliefs about the products' quality, contextual meaning and value, and they believed that products made in a school context are worth less money than other objects (Ann). One student said, "I do not believe that any of us are at a level where we can start to sell vessels" (Ane). One of the students who suggested that her vessel was worth 100 Norwegian kroner (USD 12) suggested that a similar vessel would cost 300 Norwegian kroner (USD 35) in a shop if it was professionally made (Mia). Three said that the price of a product depends on its maker, with products made by famous artists costing the most (Ann, Eva, Jon). Another student said that handmade products are unique and therefore cost more than manufactured products, which are only one of many (Mia). Two agreed that a product made by an artist can cost about 2000 Norwegian kroner (USD 234) (Ada, Jon), while a similar product from a factory could cost about 100 Norwegian kroner (USD 12) (Jon). They argued that some stores maintain low retail prices (Tom) by producing their products in countries that offer workers low wages (Jon).

Use and disposal phase* — after *the craft-based design practice

The last phase (Figure 1) of products' life cycle is use and disposal. This is the phase for which the students had designed and crafted their products. It occurs subsequently to the production phase they had experienced in the school studio. In the user phase, an environmentally considerate design ensures that the product can be safely used over a long period of time to reduce the indirect environmental impact of rapid product replacement. The students confirmed that they were aware of the environmental benefits of long-term use of utility objects in general

(Mia, Ann, Eva, Ada, Jon, Ane), and they assessed the durability of their own craft-based design products. However, as we will see in this section, a focus on the use-related qualities of products reduces one's attention on the environmental benefits these products qualities represent.

Functional qualities and products' purpose
Environmentally considerate design practices aim to create products that avoid disposal and replacement, which have a negative impact on the environment. The interview questions concerned the intended purpose of and potential improvements to the functionality of the students' products and the need for a certain number of products. Although creation of a utility object was a learning objective of the school task for the five who made vessels, the students viewed their products as decorative artefacts. This made their products less relevant as examples of functionality, which according to DfS theories concern design for physical functionality that meet needs and increase products' longevity (Cooper, 2005, p. 61; Stahel, 2010, pp. 162-163). However, the meaning of a product is partly determined by individuals and cannot be fully designed for (Chapman, 2015, pp. 42-47). Similarly, in this school task, the students imposed their own meanings and purpose onto the products they made.

The students described their products as primarily decorative artefacts with little utility function. Five made vessels (Mia, Ann, Tom, Eva and Ane), while two made sculptures (Ada and Jon). Two students said that their vessels were decorative artefacts but could also be used as flower vases (Mia, Eva). Only one described his vessel as a utility object intended to be used as a vase (Tom). Some of the students considered their ceramic products to be too large (Mia, Ann), heavy (Ann) and dominating (Eva, Ada) and therefore not easy to place, so they only need a few (Ann). Smaller glass vases (Ada) and flower pots (Ane) can be used for different purposes and occasions (Jon), and thus the students' families keep several (Ada). One student said that her vessel would have been more practical if it was smaller, but she liked it as it was (Mia).

Product emissions during use
Environmentally considerate product design practices ensure that products can be used and safely maintained without causing direct environmental impacts from hazardous emissions. The interview questions concerned the students' thoughts on maintenance of their products and the toxicity of glaze. The students drew upon their experiences with their products and the teacher's introduction of safety precautions. According to DfS theory, products must not expose humans and environments to toxins and other hazardous substances, and there is a need to regulate and phase out use of unsafe substances (McDonough & Braungart, 2009, pp. 53-63). The students' reasoned that some types of toxic glaze become safe through firing or combination with other substances, and that their teacher select materials for safe products.

The students believed that maintenance of their ceramic products merely involved dusting (Mia, Ann). They did not know whether their products could emit toxic substances, as the glaze had been toxic before firing. However, one stated that the products must be safe in use and he trusted the teacher to choose safe glaze for their project (Jon). Others suggested that ceramic products intended for food preparation have a protective coating (Mia) or undergo sterilisation before use (Ann).

Emotional qualities of personal belongings and gifts
Environmentally considerate designs include qualities that motivate users to develop an emotional attachment to a product, increasing its durability. According to DfS theory, product attachment is a commonplace phenomenon (Chapman, 2010, p. 70) that can occur when an object carries narratives and manifests memories, which are often connected to when, how and from whom the object was acquired (Chapman, 2009, p. 33). Such products can be described as living objects (Chapman 2015, pp. 42-47). The interview questions asked students about the intended owner of their products and their experiences with keeping their self-made products.

The students considered their products as personal belongings and gifts that actuate emotional attachment though memories and narratives, describing experiences with how their effort and achievement enhanced product attachment and durability, both for the products they kept and those they gave to their parents.

Two of the students intended to keep their products, explaining that they developed an attachment to it during the production process (Mia, Ann). One elaborated that the time spent making a product enhances this attachment and its durability: “I keep those things I have spent a long time making. Small things and things that takes a short time to make are quickly lost — especially those that take a short time to make because then I am not so careful about what I do with them” (Ann). Five of the students intended to give their products as gifts to their parents (Tom, Eva, Ada, Jon, Ane), explaining that their parents highly value and take good care of products made by their children (Tom, Ada, Jon) and, because their child made them (Jon), consider them to be special regardless of what they are (Eva). These students did not consider their parents’ tastes during the design process (Ane), even though they were the intended owners of the products.

Outer aesthetic qualities and craftsmanship

Environmentally considerate design practices consider outer aesthetic qualities that encourage product durability. DfS theory emphasises that aesthetic qualities, such as shape and surface, materials that age with dignity, signs of quality and crafted details, enhance a product’s longevity (Cooper, 2005, pp. 61-63). The interview questions aimed to determine students’ opinions about their products’ form and colour and what they would change if they were to make the product again. The students drew upon experiences with their products’ aesthetic qualities and revealed that the shape, size and surface with its’ colour, decoration and accuracy of glaze work determine their contentment with their decorative artefacts and, thus, their products’ durability.

The students who intended to keep their products (Mia, Ann) considered the shape and size to support the products’ purpose as decorative artefacts (Mia, Ann), although they were too wide too keep on a shelf (Mia). Overall, they were pleased with the results. One student attempted to give her product an old look by using off-white and brown colours and expected to be content with the decoration for a long time (Ann). She had considered using the colour pink but explained that this was during a ‘pink period’ and that her preference for this colour was temporary. One student who intended to give their products to their parents explained that she chose a neutral colour (i.e. white) because the product was going to be in her home (Ane), while others stated that they chose colours and decorations that matched the product’s shape (Tom) or glaze colours that their teacher had experience with successfully combining (Eva). They were less content with their products’ size (Tom), glazing (Eva), shape (Ada, Ane) and decoration (Ane).

Intrinsic product qualities and solid, repairable constructions

Environmentally considerate design practices aim to develop intrinsic product qualities that increase products’ durability. DfS theory emphasises that durability depends on intrinsic product qualities, such as resistance to wear; reliability; upgradability; high-quality materials; and robust, carefully assembled and easily repairable constructions (Cooper 2005, pp. 61-63, 2010, p. 8). The interview questions concerned students’ thoughts on the solidity and weaknesses of their products’ construction, as well as their will and ability to perform repairs if breakage should occur. The students drew upon their experiences with their products’ materials and construction to assess their products’ robustness, methods of repair and impact of repair on intrinsic and aesthetic qualities. They expressed awareness that their decision to perform repairs is influenced by the products’ aesthetic qualities as well as the value their parents and teachers place on repairing the products.

The students judged their own products to be solid (Mia, Ann, Tom, Eva, Ada, Jon), with the slimmest parts being the most fragile (Mia, Ann). They believed that they could repair the ceramic products with glue if they were to break, but these joints would be weak (Ann) and have a different colour than the rest of the product (Mia). One said that her decision to perform repairs in the future would depend on her parents' wishes (Ann), while another stated that he had already performed a repair with the teacher during the project (Jon). Three of the students (Tom, Eva, Ane) were uncertain about whether they would choose to repair their products due to their limited contentment with their products' outer aesthetic qualities.

Safely disposable or recyclable products

Environmentally considerate design practices require safe disposal or recycling of products. DfS theory stresses that that design of products with inseparable materials prevent recycling and cause downcycling of materials towards low or no user quality, moreover prevents storage of safe materials in landfills if these are inseparable from unsafe materials that can leak toxins into the environment (McDonough & Braungart, 2009, pp. 53-63). The interview questions concerned the potential for recycling students' ceramic products. The students were familiar with different disposal practices, and they drew upon the distinctive characteristics of their materials, products and production methods to determine whether it was safe to dispose of or recycle their products. Specifically, based on their experiences with plastic clay and toxic glaze, which became hard and inseparable during firing, they reflected upon whether their products can be recycled to new materials or energy or stored safely.

The students stated that they knew about recycling practices for materials such as glass and metal (Ada, Jon) but had never heard of ceramic recycling (Jon), and none thought it was possible to melt ceramics back into clay and use it to create new ceramic products. One thought it impossible to transform ceramic back into clay because the consistency of the clay became too hard during firing (Mia), while another believed that it is probably not possible to recycle ceramics because it is difficult to separate the clay from the glaze fused onto it at a couple of thousand degrees Celsius (Jon). In response to a question regarding what happens to ceramic products when they are not recycled, one student suggested that they are burned in waste incinerator (Ann), while two believed that they are disposed of in landfills (Mia, Jon). The latter suggestion resulted in mutual reflection by three students on whether it is safe to store glazed ceramics in landfills. The students reasoned that glaze consists of different metals (Eva, Ada, Jon), which are not likely to leak out in a landfill (Jon). None suggested that ceramic pieces could be reused in mosaics or that chamotte from grinding the ceramics could be blended in clay for new products, which are feasible solutions with the technology available today.

Life cycle thinking enhances design literacy for sustainability

In the analysis of the interviews, I find that the students' experiential learning through craft-based design, involved aspects that are relevant as examples of DfS practices. Further, they were able to adequately use their knowledge in reflection on environmentally considerate design solutions and environmental concerns beyond their experiences in the school's studio. This supports Nielsen and Brænne's (2013) argument for the significance of practical design and material experience to the development of design literacy for environmental sustainability. However, it is important to note that the students' environmental reasoning did not emerge out of their practices alone, but in relation to the questions; the stories described in the interviews are created through collaboration between the interviewee and interviewer (Fontana & Frey, 2008, pp. 115-119). In educational contexts, reflections are created by students, their teacher and the questions they ask. Therefore, epistemological issues emerge concerning the questions and the students' engagement with these in the case study, moreover concerning the relevance of embedding questions about products' life cycle in craft-based design education for youth. To discuss these issues, I employ perspectives on the development of knowledge for autonomy in self-determination, co-determination and solidarity taken from the theory of *kategorialen*

Bildung, proposed by the late German pedagogue Wolfgang Klafki (1959/2001, 1985/2001, pp. 101-184).

Engagement in the environmental context

Klafki (1959/2001, 1985/2001) elaborates on the process by which students develop holistic knowledge of educational topics. According to him, this process involves students' engagement with an incident, situation or item that exemplifies the topic. This example must unify the objects that culturally represent the world (e.g. classical culture or scientific knowledge) and the students' subjective critical thinking, judgement, will and imagination. Through this, the students broaden their horizons regarding the relevance of previously acquired knowledge and experiences, developing more holistic knowledge.

Using this description as a framework, I developed a triangular model of the educational practice of DfS (Maus, 2017). The model visualises the student (i.e. subject) and two subtopics: the design product (i.e. present object), which is present in the school's studio, and its environmental impact (i.e. absent object), which is absent in time and space from the studio. The bidirectional arrows visualise the students' method for engagement with these elements. The method for engagement are also educational topics for the students to learn. Below, I present a variation of this model in which the arrows represent craft-based design, LCT, TBL and DfS practice to visualise the students' engagement with the questions in this case study. The bold text indicates the area that was focused upon in this paper (Figure 2).

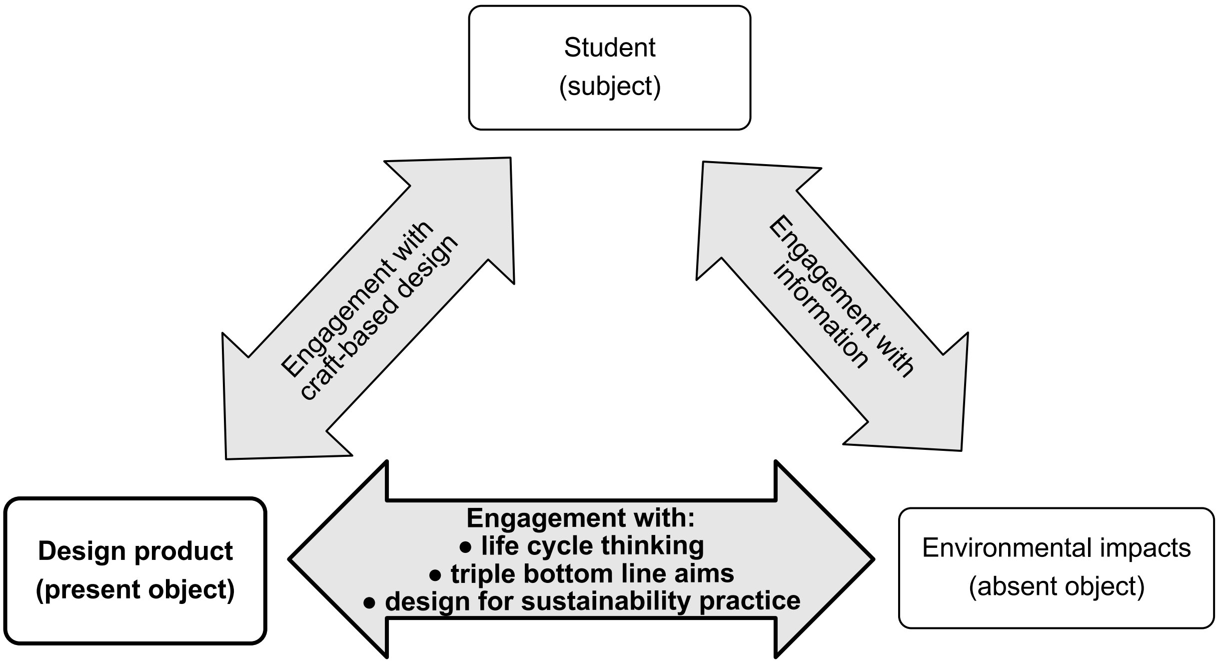

Figure 2. A variation of the model of educational practice in DfS (Maus, 2017). The bold text marks the focus of this study: students' engagement with life cycle thinking (LCT), design for sustainability (DfS) practices and the influence between their craft-based design products and the triple bottom line (TBL) aims of environmental quality, social equality and economic prosperity.

The *examples* in this case study were the items of the students' craft-based design products and the situations of their production phase, which concerned the educational topics of ceramic products and craft-based design. The students had engaged with these topics at both the objective terms of the information provided by the teacher, books and the Internet, and the subjective terms of their imagination, will, judgement and critical thinking while creating their products. Through the production phase, they developed knowledge about ceramic craft objects. During the interviews, the products were used as examples in the students' reflections on environmental considerations in product design. However, the students had not experienced examples that visualise impacts between products and environments. This because, while their products and production had been present in school studio, had the impacts been absent, as these accumulate over time in environments elsewhere. In addition, the environmental impacts of products and methods of collecting or comprehending such information were not educational topics covered by the project, and such information was not mentioned in the interviews. As one of the students said, "I am not really sure how the vessels stand in relation to nature" (Ann). Still, engagement in environmentally considerate design required the students to use some knowledge about the impact of products on the environment. So, how could the students respond to the interview questions? The answer to this, lie in the knowledge that the interview questions did introduce. A knowledge on design method, which bridge the environmental contexts in product design for suitability.

Interview questions introduced *objective* knowledge on method of inquiry for product improvements to reduce negative impacts and support environmental sustainability. These questions were based on DfS principles and practices in professional design and design education. The LCT and TBL principles provided structure for inquiries about the aims, challenges and solutions of environmentally considerate product design. The TBL concerns the aims and accounts of achievements regarding environmental sustainability, including environmental quality, social equality and economic prosperity (Elkington, 1999), while the LCT concerns the product life cycle phases in which products can cause environmental impacts and where improvements can be made. In professional design and design education, DfS principles and practices are used comprehensively to improve products before the production phase. There, LCT forms the basis for life-cycle assessment (LCA) of the data concerning products' environmental impacts (Cooper, 2005; Heiskanen, 2002). Moreover, the LCA and TBL are used as principles to embed sustainability in the studio experience in professional design education (Giard & Schneiderman, 2013). However, the use of LCT has expanded from data collection and assessment among a few production experts to become a shared concept and useful tool in design-for-environment, environmental supply chain management, environmental labelling and environmental product policy, enabling communication and empowerment among people in general (Heiskanen, 2002). From the structured knowledge on life cycle phases, researchers in the field of professional product design developed the DfS practices of eco-efficiency, eco-effectiveness and durability to ensure that resource use supports aims for environmental sustainability. These practices provide objective knowledge concerning product design for sustainability, which I employed in the interview questions. My questions related to the students' use of ecological, human and material resources to create their product, and the products' qualities decisive for their impact on the environment.

The *subjective* terms related to students' critical thinking, judgement, will and imagination were enhanced through the group interview method, which involved semi-structured questions with open-ended answers and improvised elaborative and confirmative questions. These questions engaged the students in collaborative assessment of their use of resources and the qualities of their products that determined their use of resources. Moreover, they estimated the potential environmental impact of their use of resources and possible improvements. The students based their assessments on their experiences with the products and production process as well as the design knowledge they acquired on the distinctive characteristics of materials, products and production.

The students' *holistic knowledge* about their products' impact and performance in terms of environmental sustainability was developed and expressed through their reflections in the interviews. The data analysis illuminates how the students' experiences with the distinctive characteristics of materials, products and production provided them with basic design literacy that allowed them to estimate environmental concerns. However, it was their environmental inquiries that broadened their horizons regarding the significance of design knowledge beyond the production phase in the school's studio. As one of the students said, "I don't think about it before someone asks me the question and I get to answer" (Ann). Thus, experience and reflection play complementary roles in knowledge development, echoing coherent perspectives by the late pedagogue John Dewey (Dewey & Dewey, 1915) and the late philosopher Donald A. Schön (1991). Holistic design knowledge—and design literacy for sustainability—are developed through engagement with examples of design practice and design thinking at both the objective and subjective terms. This underpins Nielsen and Brænne's (2013) argument that the environmental context should be included in craft and design to enhance design literacy for sustainability, moreover highlights the relevance of enhancing youths' design literacy through LCT and DfS practices in craft-based design education.

Design literacy for sustainable production and consumption

The overall purpose of enhancing students' design literacy for sustainability is to strengthen their ability to democratically participate in sustainable production, consumption and societal development (Nielsen and Brænne, 2013). Democratic participation requires competence to assess, reflect on and estimate consequences. As Klafki (1959/2001, 1985/2001) argued, education must enhance students' autonomy for self-determination, co-determination and solidarity in their present and future. Because students live both inside and outside the school context, this concern relates to societal development both in the educational system and beyond. I will start my discussion with the latter.

In everyday life, students are likely to handle more products purchased from a store than those they made themselves. Therefore, the main way they can participate in sustainable development is autonomy in sustainable consumption. But, how can education about LCT in craft-based design practices enhance students' design literacy regarding sustainable consumption? In the data analysis, I found that the students did not view their own products as saleable. However, through LCT, the students were able to estimate their products' influence on environmental sustainability based on the distinctive characteristics of the materials, product and production process. To reflect upon whether the materials in glazed ceramic products can be recycled, they drew upon their experiences regarding the materials and demonstrated the role of detailed material knowledge in their competence. They did not have answers to this question, but they understood how the consistency of materials changed throughout the production process. This knowledge supported their reflections on life cycle phases beyond the one they personally experienced.

The students' autonomy as stakeholders in sustainable consumption depends upon their application of design literacy for sustainability to their everyday lives. One such way this knowledge can be used in everyday life is when they encounter product information. Although international policy regulates producers' responsibility for reducing waste (European Union, 2008), waste reduction ultimately depends on consumers to make informed, sustainable choices. However, the most sustainable consumer choices are not always obvious. Firms are incentivised to engage in 'greenwashing' by promoting an environmentally friendly image through selective use of information about the positive and negative aspects of their environmental and social performance. In most cases, consumers do not have ways to assess information about the production of the products they use (Lyon & Montgomery, 2013). Therefore, consumers' competence to assess products is of substantial significance to sustainable consumption. Heiskanen (2002) highlights the usefulness of buyers and suppliers sharing the concept of LCT. With knowledge also about the possibilities and challenges of designing for eco-efficiency, eco-effectiveness and durability in products life cycles, students can understand that no single DfS practice can solve all the environmental challenges associated with a product. Rather, design strategies clarify what to expect from the design (McDonough & Braungart, 2013, p. 13). Youths' autonomy to recognise and estimate whether DfS strategies fulfil their expectations, needs and requirements makes them less dependent on the product information selected and provided by manufacturers and, hence, more prepared for encounters with greenwashing.

Recognising the different DfS practices related to the product qualities and acknowledging their opportunities and challenges are essential for sustainable consumption and should be emphasised in design education. *Design for eco-efficiency* involves low use of resources in all phases of the products' life cycle, from the cradle to the grave. This approach allows one to reduce the direct negative environmental impacts of squandering resources (Cooper, 2005). *Design for eco-effectiveness* involves cradle-to-cradle recycling and distribution of resources, allowing one to increase the positive environmental impacts of recycling biological and technical resources. However, the material separation and recycling infrastructure requirements cannot always be met by current technology. According to Cooper (2005, 2010), the cradle-to-grave and cradle-to-cradle practices for resource productivity, which are driven by efficiency, can lead to 'green growth', with increased consumption and resource throughput in the user phase of the product's life cycle. Growth in the circular use of resources also produces resources for new purposes (McDonough & Braungart, 2009, pp. 77-82). *Design for product durability* and longevity is intended to ensure a long user phase in products' life cycle. This approach enables reduction of the indirect negative environmental impacts of rapid resource throughput in the user phase due to product replacement. These practices for slow consumption are driven by the idea of sufficiency, which can cause challenges such as recession and unemployment and therefore depends on public support for a system-wide shift towards highly skilled, craft-based production, repair and maintenance (Cooper, 2005, pp. 54-55, 2010, pp. 11-14). As production for household consumption has indirect environmental impacts worldwide (Ivanova et al., 2015), the environmental benefits of DfS practices are indispensable. However, they must have public support in order to be implemented.

In design for eco-efficiency, eco-effectiveness and product durability, the consumer is not aware of the resources saved throughout products' life cycle, except for those saved in user situations. In addition, it is uncommon for these resources to be mentioned in the product information, and they are not always measurable. The three DfS practices can be combined, but they do not always support each other. For example, designing for durability may require more materials than can be reconciled with the practice of designing for efficiency or may require parts to be assembled with strong glue, which reduces the possibility of disassembly for recycling.

In summary, design and material knowledge about the distinctive characteristics of materials, products and the production process as well as knowledge of LCT and DfS practices are fundamental for assessing the possibilities and challenges in product design. These are essential educational topics for youths, as they enhance students' design literacy for sustainability and ensure their autonomy for co-determination in sustainable production and consumption.

Co-determination in the development of education in craft-based DfS

Norwegian lower secondary education is in the process of including sustainable development as an educational topic in the school subject Art and Crafts. The overall aim of both political initiatives and research on this topic is to enable youths to participate in sustainable development of society. However, although sustainable development depends upon youths' participation, intellectual contribution and ability to mobilize (United Nations Conference on Environment & Development [UNCED], 1992, para. 25.1-25.2.), are students rarely involved in research regarding development of sustainability as an educational topic in craft-based design education.

This case study illuminates the significance of the students' participation and co-determination in the development of the field of knowledge. In their collaborative reflections, they drew upon their experiences with a craft-based design project (which took 54 hours) and broadened their competence through LCT (which took approximately one hour). Their responses reveal the potential for embedding DfS principles and practices that correspond with the students' experiential learning into schools' studios. The case study starts with students' experiential learning and searches for relevant knowledge on the topic to include. This bottom-up approach contributes to the research on educational development, which has so far adopted a top-down approach to implementing sustainability in Norwegian craft-based design education for youth. The following brief overview of associated initiatives and research on Norwegian general education in design, crafts and sustainable development, structured on the curriculum inquiry framework, i.e. *ideological* political intentions, *formal* curricula, *perceived* interpretations, *operationalised* education and *experiential* learning (Goodlad, Klein & Tye, 1979, pp. 58–65; Nielsen, 2009, pp. 27–31), reveals a gap in the research-based knowledge on students' experiential learning.

The *ideological* intentions related to the implementation of principles, practices, knowledge, skills and values for sustainable production and consumption in education have been proposed by several initiatives. These include international initiatives for sustainable development (World Commission on Environment and Development [WCED], 1987, Chapter 4. para. 3.2.; UNCED, 1992, para. 36.3), education for sustainable consumption (ESC; United Nations Environment Programme [UNEP], 2010) and education for sustainable development (ESD; The United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014, 2018). National initiatives include Norway's ESD associated strategy Utdanning for bærekraftig utvikling (UBU), which focus aside production (Det kongelige kunnskaps-departement, 2012; Utdanningsdirektoratet, 2006a) and omit the school subject Art and Crafts (Melkild, 2016).

The *formal* implementation of sustainability in the Norwegian core curriculum for primary, lower and upper secondary education was conducted in 1993 (Royal Ministry of Education, Research and Church Affairs, 1999, pp. 4, 45-48) and extended as a cross-curricular topic in the core curriculum that was passed in 2017 (Utdanningsdirektoratet, 2018). The curriculum for the school subject Art and Crafts in primary and lower secondary education included environmentally conscious use of materials in 1997 (Royal Ministry of Education, Research and Church Affairs, 1999, pp. 203-217), and the consequences of products' life cycle on sustainable development and the environment in the 2006. Environmentally conscious use, reuse and long-term use of materials are emphasised in a 2019 consultation paper on a new Art and Crafts curriculum (Utdanningsdirektoratet, 2006b, 2019).

The *perceived* perspectives in research concern the possibilities of youths' development of design competence for democratic participation in sustainable development and consumption by experiencing and reflecting upon the design and crafts practice (Digranes & Fauske, 2010; Illeris, 2012; Lutnæs, 2015a, 2015b, 2017, In press; Lutnæs & Fallingen, 2017; Nielsen, 2009; Nielsen & Brænne, 2013, Nielsen & Digranes, 2007, 2012). Empirical studies among teachers in Art and Crafts concern perspectives on cultivation of eco-literacy (Fallingen, 2014) and sustainable perspectives on material use (Idland, 2015).

Operationalised educational practices are investigated in an empirical study on assessment rubrics in lower secondary school and how they value responsible creativity in art and crafts classes (Lutnæs, 2018).

The *experiential* learning of lower secondary students has been empirically investigated in this paper on students' use of experiential learning from craft-based design in LCT. Other studies have examined students' perspectives on learning environmental concerns in Art and Crafts as a key issue for operationalisation of educational practices in DfS (Maus, 2017), and enhancement of youths' design literacy for sustainability in craft-based design education (Maus, 2019).

This overview of the research in the field coincide with Goodlad, Klein and Tyes' (1979) description of the operational and experiential domains as largely uncharted territory in curriculum inquiries. In this case study, I take their advice and employ concepts for curriculum discourse, analysis and development that are similar to each other across the domains of the educational system. To examine experiential learning in relation to the formal intentions of curricula in general education, I employ concepts from professional education. I find that principles of LCT, TBL and the related DfS practices for eco-efficiency, eco-effectiveness and product durability are relevant in this context. Despite differences in the purpose, products and production methods between craft-based design in lower secondary education and professional design education at universities, the basic principles and practices of design and design education at the professional level proved to be a useful framework for education at the lower secondary level.

The students' participation with their own perspectives, are fundamental for the development of the education in the operational and experiential domains. The students' experiences with the educational practices and their critical thinking, judgement, will and imagination regarding this new educational topic, indicate how sustainability can be embedded the educational practice. Thus, they must participate in sustainable development of their education through autonomy, self-determination, co-determination and solidarity. The fields of education and educational research must ensure the democratic participation of students, as their contributions are indispensable.

Teachers' inclusion of students in the development of educational practices depends upon the teachers' qualifications. The teacher must not only engage the students in craft-based design practice, but also embed sustainability at both subjective and objective terms. The teachers' ability to do so depends upon their knowledge of fundamental DfS principles and practices and how these can be used in different craft-based design practices. I recommend that education for teachers in design, art and crafts focus on this topic in the future.

The field of research also plays a fundamental role in ensuring students' participation in research. In line with the overview of current research, operationalised education and experiential learning are nascent research topics. This case study presents the importance students' voices in research and the relevance of the design and material knowledge they have acquired at school in the studio. The results indicate the relevance of further research with focus from experiential learning of design practice towards the ideological aims of implementing principles, practices, knowledge, skills and values for sustainable development in education.

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