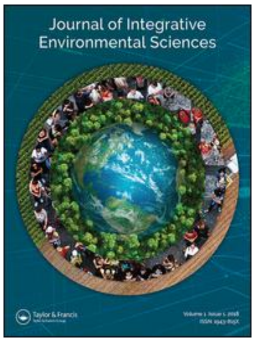

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Circular economy and Cradle to Cradle in educational practice

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ABSTRACT

This article describes how Circular Economy (CE) and Cradle to Cradle (C2C) can be used in university teaching to address these frameworks' strengths and weaknesses in practice. The advantages of these frameworks for radical change are outlined, including their emphasis on upcycling rather than recycling (downcycling). This article discusses how students apply their understanding of transformative production frameworks to three case studies of products or materials. The student projects evaluating existing products in terms of their circularity value outline a number of practical as well as theoretical challenges. The case studies demonstrate that some products still have a long way to go to fully cycle materials within a closed system. Aside from illustrating the dangers of subversion of circular frameworks to the 'business-as-usual' scenarios, the assignments are instructive in showing how CE/C2C can be successfully taught. This article recommends pedagogical strategies involving both theory of sustainable production and sustainability and practical research into company's operations in order to develop the students' ability to meaningfully engage with CE/C2C models.

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Introduction

Despite eco-efficiency gains, most products are still made *not* to last, stimulating consumers to buy new products – the practice encompassed in terms 'planned obsolescence' (Waldman 1993) and 'rebound effect' (e.g. Isenhour 2010; Kopnina 2016a) that drives continuous production and consumption (Berkhout et al. 2000).

By contrast to conventional eco-efficiency models, proponents of a steady state economy (Daly 1991) and of the de-growth movement (e.g. Alier 2009) have advocated for an end to the dominant ideology of growth (Washington 2015; Jackson 2016; Vieira 2016). Herman Daly (1991) has argued that an economy can reach a steady state after a period of downsizing or de-growth criticisingthe underlying mechanisms of denial that underlie current political and economic structures (Rees 2010; Washington 2015).

Complimentary to the critique of growth, the so-called circular frameworks aiming to address the challenge of unsustainable production have emerged. After a succession of

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concepts such as 'zero waste', 'natural capitalism' (Hawken et al. 2013) and 'green economy', the term 'circular economy' (CE) has come to the fore (Kopnina and Blewitt 2018). CE is particularly focused on circulation of materials that are produced, used and discarded in the system of industrial production (Murray et al. 2017). CE cycles materials through material and energy flows when they reach their perceived end of life questioning the very idea of unproductive or toxic waste (e.g. Cormier et al. 2006) as waste can be seen feedstock for a new cycle (Brennan et al. 2015). This understanding stems from the field of industrial ecology which basically imitates natural ecosystems and its circular cycles (Mont and Heiskanen 2015) as models for industrial production (Lifset and Graedel 2002). Crucially, in circular systems nothing expands – rather than grows naturally as in the case of plant growth (Lieder and Rashid 2016). Plant growth and 'waste' (leaves and berries) is used as food for other species and contributes to production of new soil and oxygen through photosynthesis (McDonough and Braungart 2002).

Circular systems of production were popularised through the Cradle to Cradle (C2C) concept developed by McDonough and Braungart (2002). Both C2C and CE aim to reshape the productive cycle of consumer products through a transition to an industrial system beneficial to ecological, as well as human wellbeing (Lieder and Rashid 2016). The C2C/CE frameworks' understanding of nutrient cycles translates into the need for clear planning for products that can be infinitely reused rather than recycled. Recycling in this framework is seen as downcycling, when valuable materials are reduced with each cycle (McDonough and Braungart 2002). In this sense, infinite energy sources, such as sun and wind, are seen as 'true' renewables (Marszal et al. 2011; Braungart 2013; Kopnina 2016b). The clear planning also needs to address what to do with products after their use to avoid these reductive cycles (Brennan et al. 2015). In biological (organic, biodegradable) products after-use materials can 'decompose and become food for plants and animals and nutrients for soils' (McDonough and Braungart 2002, p. 91). Eco-textiles, for example, can be used as compost after their useful life (Kopnina and Blewitt 2018), or edible film packaging can be made from milk proteins (Chen 1995). Technical nutrients (made up of durable non-toxic composite materials) can 'return to industrial cycles to supply high-quality raw materials for new products' (McDonough and Braungart 2002, p. 91). These synthetic or mineral materials need to remain in a closed-loop manufacturing system without the loss of quality (Brennan et al. 2015). Infinite re-use of the product is facilitated by production of durable materials, with the producer renting out and repairing products. The so-called Product-Service System (PSS) requires producer to retain ownership and lease products to the customers (Mont 2002). Sharing or collaborative economy is complimentary to PSS (Piscicelli et al. 2015), based on the peer-to-peer (P2P) sharing of products that are infrequently used for services that are only occasionally needed (e.g. drills for making holes) facilitated by digital sharing platforms (Piscicelli et al. 2018).

With these adjustments to the production system, C2C/CE promises a guilt-free approach that has enthused businesses, educators, and general public, drawing them into the field of sustainability (Bakker et al. 2010). While CE/C2C are critical of the current industrial production, the framework emphasises positive product ideas to complement its theoretical underpinnings (Kopnina and Blewitt 2018). Murray et al. (2017) compare many definitions of circular economy, concluding that while CE framework has multiple interpretations and encapsulates tensions and limitations, its emphasis on the redesign of processes and cycling of materials contributes to significant revision of business models. CE is defined as 'an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being' (Murray et al. 2017, p. 369).

While interdisciplinary scholarship addressing C2C and CE has emerged, education of sustainability as well as environmental education (EE) and education for sustainable development (ESD) have rarely addressed circular frameworks. This article aims to bridge this gap providing both practical case studies developed by students (and presented in the form of author-edited assignments) and a deeper reflection on theoretical challenges of applying 'ideal' models to real-case scenarios. Some ad hoc school and university level courses were developed to address CE (Webster and Johnson 2009; Andrews 2015) and C2C (Gerber et al. 2010; Kopnina 2011, 2015, 2016c, 2017; de Pauw et al. 2014). Ellen MacArthur Foundation (n.d.) has developed a number of helpful educational materials to be used at both school and graduate university levels.

Following these developments, this article wishes to complement existing scholarship of circular frameworks in education by discussing how students apply their understanding of transformative production frameworks to case studies of products or materials. This discussion is directed by an inquiry as to what pedagogical strategies need to be employed in order to address both theory of sustainable production and as well as practical skills to operationalise CE/C2C models. How can CE/C2C frameworks be used in university teaching to address strengths and weaknesses of circular production in practice?

The following sections discuss the key principles of CE/C2C, followed by the description of case studies involving students' analysis of products. The discussion section will reflect on CE/C2C in practice and education.

Key principles and certification of C2C/CE products

C2C criticises much of mainstream sustainability thinking as it tends to optimise the wrong materials through the process of eco-efficiency, 'making the wrong things less bad' (McDonough and Braungart 2010, p. 938). C2C/CE are centred around the concept of material cycling which avoids degradation or downcycling, but promotes 'upcycling' where materials, once they reach the end of their lives, become either 'biological nutrients', re-entering the environment, or 'technical nutrients', re-used in a new industrial cycle. Pointing out that if nature adhered to the human model of efficiency there would be fewer trees and nutrients, less oxygen, less clean water and less biodiversity, McDonough and Braungart (2002) have argued that the goal is to design industries able to restore and nourish ecosystems and their natural elements in a symbiotic relationship. The starting point of avoiding take-make-waste pattern of current production is the understanding that in nature unproductive waste does not exist but serves as nourishment for something new (Ibid). The purpose of C2C is to substitute harmful toxic or wasteful materials with natural and decomposable ones, or the types of materials that can be used endlessly in an industrial cycle. C2C is based on a few key principles: generating materials that are 'food' for biological or industrial systems, renewable energy, and celebrating diversity (McDonough and Braungart 2002).

The first principle, waste equals food, is illustrated by the metaphor of a cherry tree's blossoms, which decompose into new soil and thus form food for other living things (McDonough and Braungart 2002). Imitating the nutrients that flow indefinitely in nature's continuous cycles of birth, decay, and rebirth, industrial cycles can be based on biological (organic, biodegradable) and technological nutrients. Circular economy tends to put a greater emphasis on technical cycle materials that circulate within the closed-loop system of production, reuse, recovery, and remanufacture (Lieder and Rashid 2016).

The second principle, the use of infinite renewable energy. C2C systems – from construction to manufacturing – tap into direct or passive wind or solar energy sources. Unlike 'partial' renewables, such as 'waste to energy' systems, where burning actually leads to reduction of valuable biomass, the wind and sun are 'free' (Sathyajith 2006) and do not involve depletion of resources, aside from their capture and storage devices (Braungart 2013). Unlike fossil fuels, wind and solar power does not contribute to greenhouse gas emissions (Cleveland and Morris 2013). Wind and sun do not require resources that can be eventually depleted, as in the case of plant-based biofuels, nor does their production result in dangerous by-products (Renewable Energy World). Wind and sun power is potentially limitless and omnipresent, and as their harnessing, storage and transfer technology becomes more advanced, these renewables become increasingly cost competitive (Cleveland and Morris 2013; UCSUSA).

As for the third principle, the utilisation of natural diversity and locally adaptable systems, C2C draws on the idea of healthy ecosystems. These are complex communities of living organisms, each possessing unique responses to its surroundings that works in concert with other natural elements (Kopnina and Blewitt 2018). C2C takes nature's inherent diversity as a prototype, similar to biomimicry (de Pauw et al. 2014), tailoring product designs to 'fit' within local landscapes and to enhance rather than compete with or deplete surrounding environment. These innovations can range from smog-filtering towers (Braw 2015) to 'green buildings' (Steinemann et al. 2017).

These three principles are then translated into C2C certification schemes, administered, among others, by The Cradle to Cradle Products Innovation Institute (www.c2ccertified.org/). Independent accredited assessors instruct the Institute on which products meet the standard requirements of the *Cradle to Cradle Certified*™ design. Consequently, manufacturers must demonstrate efforts to improve their products. Achievement labels are assigned in each of the five categories, Material Health, Material Reutilisation, Renewable Energy, Water Stewardship, and Social Fairness. The lowest achievement level, Basic, Bronze, Silver, Gold, or Platinum, represent the product's overall mark. Following the section on teaching CE, student assignments examining existing (either certified or not) using CE/C2C evaluative frameworks products are presented.

Teaching CE/C2C

Generally, C2C and CE has been applied in education for sustainability at two levels – as curriculum (upon which this article is focused) and physical building in which education is housed, e.g. an eco-restorative school with zero carbon impacts Webster and Johnson 2009, p. 119). For curriculum development, Ellen MacArthur Foundation provides teaching and learning resources for schools and universities (Ellen MacArthur n.d.). These tools include freely downloadable lesson plans. Webster and Johnson (2009) quote Scott (2002) when discussing applications of transformative frameworks in education, emphasising the ability of educators to keep an open mind oneself as to what sustainability is. This underlies the need to 'stimulate without prescribing – and to use conceptual frameworks as support for learning, rather than as restraints on imagination and creativity' (Scott 2002 in Webster and Johnson 2009, p. 127). In the Netherlands, courses on circular economy were given at Delft

Technical University (emphasising technical innovation) and Erasmus University and The Hague University of Applied Science (both emphasising business).

Describing the assignments

This research concerns assignments collated from seven students from the Bachelor program at Leiden University College (LUC), and two students from the postgraduate program (Masters) at the anthropology department at Leiden University (LU). These students have chosen to investigate drinking containers and other packaging as part of the sustainability-related course. The course 'Environment and Development' was taught between 2016 and 2017 at both LU and LUC and was intended to combine both technical and business aspects of C2C/CE, with an added emphasis on critical analysis of real-life cases using 'ideal' framework principles. During the course, students were asked to reflect upon possibilities and potential pitfalls of designing C2C/CE product, evaluating the product as the best-case practice or a case of green washing. The students were asked to use the following steps:

(1) Read assigned literature (some of was used in the Introduction of this article).
(2) Pick one of the corporate case studies from the following websites https://mbdc.com/portfolio/ or http://www.ellenmacarthurfoundation.org/case_studies/
(3) Consult assessments: https://mbdc.com/how-to-get-your-product-cradle-to-cradle-certified/ and http://www.c2ccertified.org/get-certified/product-certification or http://circulareconomytoolkit.org/Assessmenttool.html
(4) Decide on what can be done better to comply with the specifications for C2C certification.

The case studies described below are abridged and author-edited versions of student assignments retaining most of students original references and conclusions. The researcher has followed European Council's code of research ethics (http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/ethics-guide-ethnog-anthrop_en.pdf, p. 42) in regard to data protection. Students who objected to their assignments being used were excluded from analysis. Although assignments were not submitted anonymously, original information that was linked to individuals was kept in a password-protected file separate from anonymous files researcher worked with.

Case 1. Water bottles

There are good reasons to stop using single-use plastic bottles and switch to tap-filled reusable water bottles. Are these reusable bottles really as sustainable? In this essay, three water bottles will be coampred on natural resources used, recyclability, reusability, manufacturing and distribution.

A popular reusable water bottle will be abbreviated here as DD. In 2014, DD sold around 700.000 units and over 1.3 million in 2015, almost doubling their sales and raising their turnover from just under €4 million to over €7 million in 2015 (DD Annual Report 2015). DD aims to reduce the amount of single-use plastic and improve access to safe drinking water. Five per cent of its net turnover goes to DD foundation, which works with its partner organisation to install 'safe drinking water systems and toilets' in Nepal.

Though DD may be raising awareness about the impact of single-use plastic, they are not drawing essential links between western overconsumption and environmental degradation. A customer on DD website reflects this problem: 'DD is our handiest bottle! We have five of them'. However, if everyone had a DD and maintained it, production of PETE bottles might decline, but this further places responsibility on consumers. DD bottles costs €12.50, which is 12 times the price of an average single use bottle. Sustainable products often cost more, which makes them unreachable for low-income consumers. However, 'bottled water retails at up to 500 times more than the price of tap water', which suggests, in the long-run, DD is a money-saving purchase (Environmental Technology Centre). DD has a C2C certificate because there are no toxic substances in it, such as BPA. The Foundation's projects contribute to social welfare and the thermoplastics are 100% recyclable. Customers can return their old bottles to DD or recycling points. 'DD makes a major contribution to reducing the global plastics problem' (DD C2C 2015). However, DD does not mention what percentage of the bottles is made from recycled materials. DD says that 'dD is produced in a climate-neutral fashion, with responsible water and energy use', but this is not explained in detail. While DD was awarded Gold for the category of 'Renewable Energy and Carbon Management', it only received a Bronze for 'water Stewardship' (C2C 2014). DD states that their goal is not to make a profit but to make a positive impact for a better world; however, only 5% of their net turnover goes towards to the foundation. Where does the rest go? DD demonstrates the current emphasis on lifestyle choices within sustainability discourses and does not address issues of corporate and political regulation that could potentially ban the sale of PET bottles. A DD bottle consists of a cap, cup and the bottle itself. The cup is made of ABS plastic. According to the European plastic trade association PlasticsEurope, industrial production of 1 kg of ABS resin in Europe uses an average of 95.34 MJ and is derived from natural gas and petroleum. TPE plastic is used for the ridges inside the bottle, to prevent it from leaking. The bottle itself is made of polypropylene. Poly(propene) is produced from propene derived from gas oil, naphtha, ethane and propane.

After consumers are done with their DD or if their bottle is damaged, parts can be returned for free and will be recycled into future DDs. DD claims to be made of 100% recyclable materials. As virgin ABS is somewhat expensive, recycling ABS is economically very attractive. Recycled ABS can be blended with virgin material to produce products with lower cost while preserving the high quality. The recycling process of polypropylene requires collection, sorting, cleaning, reprocessing by melting, and producing new products. Plastic waste should be considered as a valuable secondary resource that can be used to save energy and prevent GHG emissions. However, energy recovery of plastic waste in MSWI (Municipal solid waste incineration) plants at current European conditions produces more CO2 than it prevents because of electricity used and district heat production, making it an unsustainable option (Pilz et al. 2010).

Another drinking bottle company that will be referred here as KK. In 2004, KK introduced the 27oz bottle to give people a better option than plastic bottles: 'a safe, healthy, lightweight, reusable bottle free of BPA and other toxics'. KK are a certified B Corporation, trying to create the highest quality reusable products, as well as bringing awareness. KK partners with non-profits and environmental organisations working to educate the public about health and environmental issues. KK became a member of 1% For The Planet in 2008 and donated more than 1% of their annual sales to nonprofits. They also claim to have business policies that support environmental and fair labour practices, however just as with DD, nothing specific as to what this entails is mentioned. KK bottles are made of 1 stainless steel, which includes 18% chromium and 8% nickel, with other metals being manganese, silicon, copper, carbon, nitrogen, phosphorus, molybdenum, zirconium, and titanium (KK.). Nickel is a naturally abundant element found in the earth's crust, soil and ocean floor. Chromium is mostly mined in South-Africa, Kazakhstan, Russia, and India (Sverdrup and Ragnarsdóttir 2014). The Bottles are 'hand crafted' in China. KK buys Renewable Energy Certificates that offset the environmental impact of their electricity use (EPA n.d.). Orders are send via UPS Ground by truck in the US (KK). Customers cannot buy directly from KK outside the US, only from shops that stock the bottles, which limits shipping by plane or tanker (Ibid). The company guarantees that a portion of shipping costs goes towards buying carbon offsets, projects that absorb and capture carbon (KK Shipping 2016).

All together the materials used in the KK are recyclable, 18/8 stainless steel is a sustainable material, having a long service life (Sverdrup and Ragnarsdóttir 2014). Stainless steel produced in a melting process contains chromium and nickel which makes recycling stainless steel economically viable. Thus, stainless steel often remains part of the sustainable closed-loop system or recycled without any degradation (International Stainless Steel Forum). However, as stainless steel objects hardly ever become waste at the end of their life and the estimated End of Life Recycling ratio is 80–90%, virgin material might be required if all usable steel is still in use. However, on the KK website they state that many of their products are recyclable, so not all, which seems contradicting with their goals. There is a lifetime guarantee on the KK bottles, even though they do not specify whether and how bottles can be returned for repair. DD is not necessarily made for infinite reuse, but as the website suggests, if you take care of it, you could use it for a long time (DD n.d.). Single use plastic bottles are made of Polyethylene Terephthalate (PET), which make products softer and more flexible. Phthalates have been linked to cancer (Keresztes et al. 2013). Single use bottles also contain antimony, this can cause negative health effects such as nausea, vomiting, and diarrhoea when exposure exceeds the tolerability levels for relatively short periods (Rungchang et al. 2013). Locally sourced water is often delivered by truck. However, this does not mean that filled bottles are not shipped by tanker/plane when exported.

PET bottles are manufactured in a mixer, which combines PETE pellets with recycled PETE flakes. Recycled content cannot exceed 10% as reprocessed plastic loses its physical properties. The mixture is heated to 315C by a plastic injection machine and is then injected into moulds creating 'preforms' or starter shapes. The preforms go to a reheat stretch blower moulder where they are heated and stretched lengthways using a rod and blown air. Cold water is then used to set the mould. One machine makes 10,000 bottles an hour (Plastic bottles 2013). The main resources used to produce the bottles are non-renewable. However, the collected PET can be recycled (Hopewell et al. 2009).

PET bottles' negative effects are due to petroleum used for manufacturing and transportation. Chemicals that the bottles contain, which may harm consumers' health and even though the bottles are recyclable most end up in landfills which can stay there for hundreds of years without decomposing. These piles of plastic garbage threaten our wildlife.

DD bottles seem like a positive alternative, made from recyclable materials and made to last a long time to prevent waste. However, the distribution and manufacturing process of DD does not seem to be so 'green'. The use of fuels and packaging make up for the positive elements DD has to offer. DD does not state how much of their bottles are actually made of recycled materials. Another downside is the unawareness with DD customers about where to bring their DD once done with it, resulting in bottles still ending up in regular trash bins. KK seems to be a viable option with its recyclable material, both in the bottle as in the packaging, and ability to last a lifetime. However, KK bottles require a huge amount of energy to be produced, including shipping. Even though KK donates a percentage of these costs to good causes, damage is done. In terms of material wise, the thin PET bottles have the lowest environmental impact. However, since they are only used once and cause landfilling. KK bottles have the largest environmental impact, mainly because of the oil and the production process since more energy is needed to form steel into a bottle shape than the easily moulded plastic.

So far neither one has reached a real sustainable water bottle. A good alternative might be bamboo bottles. Bamboo is extremely durable, cost effective to use, strong, reusable, recyclable, grows fast and without pesticides. Beside that one hectare of bamboo scrubs 62 tons of carbon dioxide per year and generates up to 35% more oxygen than an equivalent stand of trees (Bamboo bottle) and bamboo is stronger than many alloys of steel. Abundantly bamboo is used in Asian indigenous communities bamboo is being used as cups (Bhatt et al. 2003).

For commercial use and to adhere to C2C requirements, however, the bottles should be made locally to prevent negative environmental impacts through distribution. A downside is that bamboo naturally grows in countries around the equator, certain types of bamboo can be grown in other countries as well but not all kinds. Also, the manufacturing process would most likely still use some kind of fossil fuel. Another example is 360 Paper Water Bottles, which uses a method of making packaging whereas several bottles can be aligned without the need for a Separate 6-pack carries. Natural cardboard is used with vertical breaks, which reduces the material for palletising and transport but it certainly does not eliminate the use of paper. As modern societies become more environmentally aware, we have made positive strides towards sustainable lifestyles. However, not everyone (individuals, corporations, governments) abides by these practices, opting for convenience over eco-friendliness and a lot still has to be achieved in striving towards sustainable eco-friendly products.

Case 2. Mushroom Materials

Most foods are wrapped in plastic packaging. One of the most common packaging materials is styrofoam, also known as 'white pollution', which is 'thrown from the windows of trains and it takes 200 years to decompose, even when buried […] it can be poisonous for animals' (Edmonds 2006, p. 124). Plastic foam is made of oil, which breaks down into micro-plastics that pollute oceans and soil (Li et al. 2016). Not only does this create non-biodegradable waste, but some plastics are suspected of leaking harmful compounds into food (Bouwmeester et al. 2015).

When plastic is recycled, it produces a hybrid of lower quality molded into something cheap that might not be recycled again once used. Downcycled plastic can contain more additives than the 'virgin' one, as chemicals and minerals may be added to attain the desired performance quality (McDonough and Braungart 2010, p. 56). In fact, when plastic is melted its polymers shorten and some properties such as elasticity, clarity and strength are lost. As McDonough and Braungart (2010, p. 56) note, 'The creative use of downcycled materials for new products can be misguided […] people may feel they are making an ecologically sound choice by buying and wearing clothing made of fibers from recycled plastic bottles'. Rebound effect (Berkhout et al. 2000) is also present since the 'fibers obtained from plastic bottles contain toxins such as antimony, catalytic residues, ultraviolet stabilizers, plasticizers and antioxidants, which were never designed to lie next to human skin' (McDonough and Braungart 2010, p. 56).

Eben Bayer (2010), founder of Ecovative Design, has stated:

> There are three principles that should govern better materials. Firstly, they should be able to be created almost anywhere on the planet. Secondly, they should require considerably less energy to produce than current materials. Lastly, they should be able to be disposed of by nature's wonderful open-source recycling system.

It is essential for eco-effective product to maintain or even enhance the quality and productivity of materials through subsequent life cycles. These principles are applied in the C2C case study of Ecovative's MycoFoam or 'Mushroom Materials' are a bio-based alternative to plastic foams (Ecovative n.d.). Ecovative, a company based in New York, uses specific fungus to grow materials into any shapes out of bio-waste (usually ground up corn stalks) and mycelium (C2C Mushroom Materials n.d.) Ecovative's process uses mushroom-related technology to convert agricultural waste such as corn stalks and cotton burrs into a material designed to be home compostable. The primary function of mushroom packaging is to protect products by cushioning a product, so it does not get damaged when transported. The Ecovative sells mushroom packaging to Dell, Rich Brilliant Willing and Stanhope Seta (Ecovative n.d.).

Mycelium (which is a type of mushroom's roots) is used to bond together crop by-products such as seed husks or stalks. The mycelium growing process happens indoors, in the dark, in less than a week. The resulting 'Mushroom Material' is then dried in order to stop the mushroom's growth. 'Mushroom Material' is produced for many applications, including as 'Mushroom Packaging', which replaces EPS, EPP, and EPE (oil-made and non-biodegradable plastics) foam packaging parts. In addition to protective packaging, 'Mushroom Materials' are also in use or are being developed for plaques, automotive components, insulation boards, structural insulating panels, ceiling tiles, acoustic panels, marine degradable buoys, and more. The foam is used to protect electronic devices, furniture, wine bottles, ceramics and glassware, among other products. Myco Make uses the Do-It-Yourself (DIY) and Grow-It-Yourself (GIY) techniques. GIY Mushroom® Material, a mixture of mycelium and corn stalks/husks, needs some water and flour to come back to life, and has been used to grow a wedding dress, lamps, and Hy-Fi towers (Ecaovative n.d.).

MycoFoam is naturally buoyant and can withstand salt water for 2–3 months before breaking down. The Ecovative factory is exploring coating techniques that will allow the material to sustain longer, but still decompose when the product is no longer wanted or lost at sea (Ecovative 2016). Mycofoam has been rightly certificated as a 'gold' product. It also won the '2011 Du Pont packaging awards' as a 'Diamond winner', and the 'Greener package award' in the Non-FDA-Regulated Products category. According to C2C criteria, MycoFoam is a good solution as it is 100% biologic-based, also offering a nontoxic and convenient end-of-life option, for both aerobic and anaerobic compostability, and can be used as mulch or left to decompose. Plus, it produces neither spores nor allergens. Ecovative is using renewable resources for production. It is a perfect example of what McDonough and Braungart (2010, p. 1280) describe as a 'worry-free packaging', which could decompose, or used as fertiliser, bringing nutrients back to the soil. Back to the example of 'white pollution', if mycofoam were thrown off the trains it would fertilise the soil.

Mycofoam supports and promotes edible products. Several objects have been already created, from edible cups made of seaweed to edible food packaging made of rice or milk protein, able to substitute plastic packaging. Alternatives are under way. An example of edible product container is 'Scoff-ee Cup' made of biscuits and white chocolate, able to withstand the heat, created by the team 'Robin collective' for the Kentucky Fried Chicken (KFC). Another example is the 'Loliware edible cups' (https://www.loliware.com/), made of seaweed named 'algar'. Edible packaging films are polymeric films based on edible materials that can 'provide physical, chemical and biological barriers between a food product and its environment' (Bonnaillie et al. 2014, p. 1). The protein-based films, such as milk proteins, are used for films and coatings (Dangaran et al. 2009) as powerful oxygen blockers, diminishing the chance of food spoilage (Tomasula et al. 1998).

Mycofoam can replace plastic packaging and can help promoting the spread of biodegradable plastics. In 2005–2006 food packagers in Europe experienced a 30–80% increase in the cost of packaging materials, mostly due to escalating cost of petroleum (Dangaran et al. 2009). A food packaging made of milk protein or rice would be cheaper and completely biodegradable (Bonnaillie et al. 2014). MycoFoam is deservedly a 'gold certified cradle-to-cradle product' and a successful example of biodegradable plastic, saving the government the hassle of providing a system to collect and process plastics. It is made of natural raw material, which is composted instead of landfilled.

The one time during the life cycle of a MycoFoam product when pollution is created it is transportation. This particular phase can be replaced with more ecological alternatives.

Discussion: business as usual or radical transformation?

A number of scholars have expressed their concerns as to just how realistic the transition to C2C/CE production is. Kirchherr et al. (2017a) note that the circular economy is most frequently depicted as a combination of conventional 'reduce, reuse and recycle' activities, that CE necessitates a systemic shift. Kirchherr et al. (2017a) also warn that the primary goal of CE seems to be economic prosperity, followed by environmental quality; with its impact on social equity and future generations is barely mentioned. More generally, despite all the supposed achievements of sustainable technologies in CE, the basic fact that increased human consumption calls for increase of resources remains paramount (Rammelt and Crisp 2014). Both increase in human population and material needs leads to depletion of natural resources and the challenge of decoupling economy from resource consumption (Washington 2015). While absolute decoupling promises that the environmental impact will decrease as GDP grows, no empirical evidence is available that this is happening (Rammelt and Crisp 2014).

This calls for deeper questions to be discussed with students during classes on circular economy (some results were already reported by Kopnina 2017) including how far products and processes that profess to be circular can actually decouple throughput of resources and our consumption. The challenges of C2C/CE frameworks are illustrated by the student projects in determining how far consumables can be 'sustainably' produced and packaged. The students discovered companies focus on recycling (downcycling) and eco-efficiency (minimising but not eliminating damage), not reaching deep enough for fundamental change. Also, some companies listed as C2C certified such as DD seem to improve some parts of their operation, without the needed overhaul of the *entire* mode of operation. The example of

MycoFoam illustrates that both more natural and innovative designs have a more tranformative potential.

Another challenge discussed in classes is how to actually make circular production possible. As Kirchherr et al. (2017b) have outlined, there are the cultural barriers of lacking consumer interest and awareness as well as a hesitant company culture. These barriers are similar as to those reported for sustainable behaviour that requires not just consuming differently or consuming less but stopping consumption of products that are not sustainable (Isenhour 2010). During class devoted to discussing students' own consumer behaviour the difficulty in stopping consumption rather than switching to buying 'green' products was emphasised. Changing the consumers behaviour is challenging given a gap between awareness and the action that is restrained by social, lifestyle, economic and political barriers (Isenhour 2010). Encouraging *less* consumption is contrary to today's neoliberal economic thinking (Kopnina and Blewitt 2018). Without mutual cooperation between governments, producers and consumers, the contemporary focus on consumer responsibility and choice is not likely to 'result in significant long-term change' (Isenhour 2010, p. 466). The opportunity lies in new financial opportunities created by the PSS – development of functional service economy that leases products to the customers, as well as monitors and repairs them (Mont 2002; Piscicelli et al. 2015). Within educational practice this implies the need for greater reflection on strategic ways of addressing sources of power and decision-making in making circular frameworks more viable. Didactically, students can be taught to critically examine government policy and corporate institutions as sources of potential reform, and to distinguish between what is ideal and what is feasible in real-case situations. The cases described here reflect that students are able to see some companies as more or less understanding and adhering to the circularity principles, and are able to distinguish certain features that identify possible 'pioneers' of change. Consequent research could expand upon this understanding.

While C2C/CE may be more prominent in literature (e.g. for an overview, see Murray et al. 2017), the concepts and practical implications seem to be a niche discussion among sustainable development professionals (Kirchherr et al. 2017b) and in literature on education for sustainability. As Kirchherr et al. (2017b) also note, market barriers include low virgin material prices and high upfront investments costs for circular business models. Government intervention might be needed to overcome the market barriers (Kirchherr et al. 2017b); however, granted reluctance of neoliberal governments' to regulate industry (Isenhour 2010), it remains to be seen whether such regulation is possible.

Considering that almost all production, particularly of beverages or food, requires the transformation of raw materials, the scope for decoupling seems limited (Hawken et al. 2013). While with relative decoupling, the growth of environmental impacts slows down relative to GDP due to efficiency improvements, absolute decoupling failed to deliver on its promise that the environmental impact will decrease as GDP grows (Rammelt and Crisp 2014). Some form of relative decoupling might be occurring, but even the 'best case study' products such as DD bottle fail to deliver a product that can be eternally re-used, let alone upcycled. Reduction (rather than complete elimination) of raw materials is possible, but complete circularity seems questionable.

Even if the bottles were changed to 100% plant-based bioplastics or clay (and thus biodegradable) materials, the challenge of scale might be insurmountable. Bioplastics require plantations of monocultural crops, as in the case of palm oil. Another challenge is to produce the 'good' products on such a scale that they push out all other less sustainable options (Kopnina and Blewitt 2018). Providing these plant-based containers and contents to over seven and a half billion people without environmental depletion might be too optimistic. While competition is not new in business, restricting market choices is not something that neoliberal economies or governments like to do (Isenhour 2010). Also, while producers need to use local plant materials to achieve C2C certification, their product needs to reach the greatest number of consumers to replace less sustainable options. In the case of MycoFoam, for example, one needs to ask whether this material can be successfully introduced at a larger scale to replace all others without the need of mono-cultural production and how transportation-related emissions can be addressed.

Perhaps instead of teaching how to retain the same consumption level and reduce environmental impact, environmental educators need to discuss with students what do they consider to be a fulfilled life that is based on non-material benefits. In *Prosperity Without Growth,* Tim Jackson (2016) has observed that the dream of a growing economy allows for a 'catching up' by the poorest, without much sacrifice of their lifestyles by the rich, basically having your cake and eating it. Since 'decoupling' usually means that we reduce the amount of materials and energy used to make a unit of GDP, GDP growth might be a poor proxy for human well-being and a sustainable societal goal (Kopnina and Blewitt 2018). In the long term, Jackson (2016) warns, not just natural resources will be depleted but society and economy might collapse. To avoid this, at educational level this requires pedagogical strategies that involve in both critical reflection on theory of sustainable production and different business models, such as de-growth and steady-state economy (Daly 1991; Alier 2009; Hawken et al. 2013; Washington 2015; Jackson 2016); as well as practical components (e.g. desk research into company's operations or direct involvement through internships) that sharpen students' ability to distinguish and compare applications of CE/C2C models.

Conclusions

Using the assignments, and comparing 'ideal' framework specifications with 'real life' products, case studies illustrate how difficult it is to implement sustainability in practice. The case studies indicate the challenges of substituting virgin (in the case of KK), recycled (in the case of DD), or mixed materials for those that can be infinitely reused. As students noted, even the supposedly 'best case study' drinking bottles cannot be upcycled. Thus, while reduction of virgin materials may be possible, the ideal circularity seems questionable. In the case of KK, virgin steel might still be required as this material is in fact so durable that most of it is currently in use and not available for re-use. As population expands and material demands do not subside, the solution to the use of virgin materials is the turn away from built-in obsolescence models to the use of materials already existing in technical cycle. In the case of DD, the students note that clever green marketing circumvents a major breakthrough in decoupling production from resource consumption resulting in rebound effect (Berkhout et al. 2000). The solution to this is continuous vigilance on behalf of consumer organisations, NGO's and other independent observers that may move companies towards honest reporting – at least for the sake of Pubic Relations (PR). Part of this effort is educational initiatives encouraging critical reflection on the publicly available data published by manufacturers (e.g. their annual reports, which may not be objective).

While this article discusses how C2C and CE frameworks can be subverted to 'business-as-usual' practices in the case of drinking bottles, the author sees great merit in teaching about applicability of circular frameworks to real-life cases. The students learn from 'bad' or 'mixed' examples that the challenge of circular production is not easy to overcome, but that opportunities are present. In the case of MycoFoam, the students reported how products can enrich the soil when discarded. Students made recommendations as to how products and processes can be made more in line with ideal aims of C2C/CE (e.g. supporting bamboo bottles or edible cups), but also emphasised areas such as limits to material growth. As one of the students have noted after completion of the course, at least theoretically C2C/CE can lead to 'true' sustainability – a positive learning experience, and an empowering one.

Returning to the quote about the 'need is to stimulate without prescribing' (Scott 2002 in Webster and Johnson 2009, p. 127), the author of this article partially agrees. As educational practitioner, it is easy to agree that discussion of C2C/CE should support learning. However, prescriptions in a sense of clear explication of 'ideal' framework can guide students into judging what system of production is better than others. To continue expanding on practice of critical teaching for sustainability, possible bottlenecks and pitfalls involved in 'real-world' production need to be considered by educators. The role of education in promoting C2C/CE can contribute to developing citizens that might become designers, manufacturers, policy-makers and businessmen making the transition to circular economy a reality.

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