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The role of education in promoting circular economy

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ABSTRACT
The environmental problems caused by a linear economy system and the exploitation of natural resources have been known well over 50 years. Although a great deal has been done, there is a contradiction between increasing consumerism and the concrete actions that have been taken. A lot more needs to be done immediately to stop catastrophic global change and adopt circular economy mindset and system. The most profound way to promote this transformation is to involve all people through education. Starting in pre-school and continuing all the way to university, education is the best way to enable the transition from a linear economy to a circular economy. In this article, we describe how a project to implement circular economy teaching in the Finnish education system was carried out. We also show that the teaching development should be started from the bottom up with teachers, as opposed to top-level planning bodies. The first target in Finland’s circular economy education programme was to focus on today’s school pupils and university students. However, this is not enough. There is an increasing need to involve everyone in working life to increase their circular economy skills. The aim is that everyone is a circular economy expert.

Introduction
The world economy is based on the linear use of natural resources, from raw materials to products to disposal. The problems with such a system were noticed over 50 years ago in the first Club of Rome report ‘Limits to Growth’. Despite the awareness of the impact and consequences that this type of human behaviour is responsible for the current sustainability crisis, the situation is getting worse rather than better. The linear economy system and increasing consumerism coupled with the world population doubling in size – from 4 billion in 1975 to 8 billion today – leaves us more or less in the same situation, overusing the planet’s resources (Meadows et al. 1972; Sachs and Pan 2015). A significant cultural change is needed in order to achieve sustainability, even though a change from a culture based on consumption to one that is not materialistic is not an easy thing to accomplish. (Kirchherr et al. 2018)

The sustainability crisis – including climate change, biodiversity loss, overusing natural resources and pollution – needs action now. The most important action is to stop endless consumption, along with the transition from a linear economy towards a carbon-neutral circular economy (CE). Integrating CE into society and the global economy requires complex and dynamic (systemic) changes in technical and behavioural aspects. (Bertassini et al. 2021) These changes involve every sector of society. In order to create a more sustainable society, it is crucial that the people understand the importance of decreasing their consumption. Furthermore, there is a need to increase knowledge on the CE and new solutions in society and our everyday lives. Without concrete tools, it is hard to make changes to our daily routines.

It has been shown that progress in environmental awareness contributes to decreasing environmental impacts (cf. e.g. Shen and Wang 2022; Venghaus, Henseleit, and Belka 2022). Therefore, environmental thinking should be included at all the levels of education. Children and youths are well aware of the global state of the environment and want to be part of the solution, not part of the problem. In order for that to happen, they need education in environmental issues – problems and solutions.

In this article, we contend that a lack of knowhow is a significant obstacle in the transition towards sustainability. If a person does not know how to act differently, it is easier to continue ‘as I always have done’. This article demonstrates that the best way to start transitioning from a linear economy towards a circular economy is to educate people. In the first part of the article, we focus on the national project of implementing CE thinking in the educational system. In the second part, the focus is on university students and their current knowledge of and interest in sustainability and CE. Based on the interviews conducted, it is clear that there is a demand for CE education. Consequently, there is a need to develop CE education and comprehensively implement at all levels of education.

The aim of this article is to provide an overall picture of systemic change needed in transitioning to circular economy and especially the role of education in this transition.
The article is based on two case studies. Case study I focuses on the national project of integrating circular economy thinking and education into all levels of the Finnish educational system. A ‘learning by doing’ research approach was used. Case study II focuses on university students and their views on CE. To date, there have not been many studies on the views of students in technical fields. The viewpoints from Canada, yet another western hemisphere country from another continent, are included in the article for comparison.

In order to achieve an economic model that works within the limits of the planet’s carrying capacity, the circular economy must be the prevailing economic model worldwide. Experiences in Finland and Canada can be used to demonstrate how CE education is playing a crucial role in the transition towards sustainability and a carbon-neutral CE society.

The main research questions were:

1. How to implement and integrate circular economy education in the national education system (Case study I)
2. What do university students studying in a technical field perceive as barriers to and drivers of the circular economy? (Case study II)
3. How do university students studying in a technical field see their role in promoting the transition towards a carbon-neutral circular economy? (Case study II)

Our research shows that, in order to tackle wicked problems – climate change, biodiversity loss, pollution and the overuse of natural resources – there is a need to increase understanding of the situation and competences in CE. Finland was the first country in the world to publish a CE roadmap. One of the outcomes of the roadmap was the CE education programme presented in the Case study I. From a novelty standpoint, the study presented in this article is the first of its kind.

There is a large demand and interest for CE education worldwide. Project leader Nani Pajunen has presented the results published in this article at many conferences and webinars, including Ellen MacArthur Foundation’s Higher Education Workshop: Circular Economy Teaching & Learning on 20 June 2018; ‘All Levels of Education Towards Circular Economy. Circular Economy Teaching and Learning’ at the Meeting of Directors-General for Vocational Education and Training (DGVET) on 4 October 2021; ‘The transition towards a carbon neutral circular economy requires new knowledge and skills’ during the European Vocational Skills Week ‘VET for ALL – Skills for Life’ in October 2019 ‘Towards Carbon Neutral Circular Economy Society – How to get there?’ and at the UNESCO World Conference on Education for Sustainable Development in May 2021 ‘The circular economy needs new kinds of skills, actions and operations’.

This article starts with a literature review of the main concepts used. In Materials and methods, we describe first what is a case study approach. After that we describe how the research material was collected and analysed. The Results chapter consists of a deeper review of the results of two case studies and is supplemented with a short chapter on the experiences in Canada with implementing CE teaching at different levels in the education system. In Discussion, we examine the results in more detail and the strengths and weaknesses of this article. Finally, in Conclusions we discuss of the results, how to apply them, and present some ideas for future research.

Literature review

A literature review was done on the main concepts and phenomena addressed in the article. Searches were done using different search engines, mainly in English, but also in Finnish. A more detailed search was done on the mining industry and architecture from a circular economy education standpoint. A keyword search of the drivers and barriers to change was done generally as well as field-specifically. Certain basic resources, such as UN and IPCC publications were used to define different concepts and phenomena.

Circular economy

Dating all the way back to the 1980s, the term ‘circular economy’ (CE) originated from two interrelated ideas: a closed-loop economy and the ‘design to redesign’ thinking. The idea of CE is, on one hand, to manage or restore the flow of biochemical cycles and material cycles and, on the other, to promote recycling. The three pillars of CE are social, economic and environmental sustainability. It is an economic model where both the process and output of planning, resourcing, procurement, production and reprocessing are designed and managed in order to maximise ecosystem functioning and human well-being. (Murray, Skene, and Haynes 2017) The aim of CE as an economic system is a restorative and generative model that aims to maintain the value of products, materials, and resources and, as a result, minimise the generation of final waste. (Ranta et al. 2018)

The term circular economy is used in two senses. First, a carbon-neutral circular economy is a goal towards which we are striving. Second, we can use circular economy as a solution, an action and a tool for making a more sustainable future for humankind and nature.

A carbon-neutral CE as a goal means a global economy based on the sustainable use of natural resources and operating within the limits of the planet’s carrying capacity. CE as a tool means, for example, CE business models (see Table 1), such as product as a service, product-life extension, sharing platforms, renewability and resource efficiency and recycling. (Sitra’s Circular Economy Playbook for Finnish SMEs. 2018)

The core of the CE is to keep resources in use as long as possible. This means that whenever we use natural resources, we have to ensure at the beginning of lifecycle that they remain in use after their first use. The tools, such as material and product passports, are created for this purpose. (Benachio et al. 2020)

Figure 1 shows the lifecycle of any material or product with the systemic level approach (1). We need raw materials (i.e. natural resources or secondary, recycled, materials), water and energy (2) for industrial processes, in which we produce different goods and commodities for the market. When trying to tackle the sustainability crisis, there is a need to make changes all the phases of lifecycle. The goal is to create wellbeing with less material.
CE means new kinds of competences and skills in business, design, planning, materials etc. In Case study II, we interviewed mining and mineral processing engineering students at the University of British Columbia (UBC) in Canada and architectural students at Aalto University in Finland and Yale University in the United States. They all consider their role at the beginning of the lifecycle to be very important. The most important decisions are made before anything concrete happens in the design and planning phases. The design phase is crucial when planning sustainability or circular economy. (Bocken et al. 2016; Ceschin and Gaziulusoy 2016)

### Sustainable development

One of the earliest and the most comprehensive definitions of the concept of sustainable development was introduced in 1987 in the Brundtland Commission Report on the environment and development. According to the report, sustainable development is a process in which technological development, use of resources, investments and institutional change meet ‘the needs of the present without compromising the ability of future generations to meet their own needs’. The report also states that promoting sustainable development is a political decision. (Brundtland WCED 1987) Since the report was published, the concept of sustainable development has become well established.

In 1992, when the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro, Brazil, sustainable development issues were considered to be the domain of science and technology. At the conference Agenda 21, the Rio Declaration on Environment and Development, and the Statement of principles for the Sustainable Management of Forests were adopted by more than 178 Governments. Agenda 21 consists of four sections: Social and Economic Dimensions; Conservation and Management of Resources for Development; Strengthening the Role of Major Groups and Means of Implementation. One of the means is promoting education, public awareness and training. (UN Agenda 21)

United Nations’ resolution Transforming our world: the 2030 Agenda for Sustainable Development was published in 2015. There are 17 goals for sustainable development (SDGs). As we mentioned earlier in this article, circular economy is a new kind of global market economy. From that perspective, CE is part of the solution in all of the set 17 goals. For example, a CE system would be crucial in achieving the SGDs, especially those concerning healthy living and well-being, ensuring clean water and sustainable consumption. CE is crucial also in combating climate change, conserving the use of the oceans and seas and terrestrial ecosystems. In order to achieve this, SGD 17 is the most important: Strengthen the means of implementation and revitalise the global partnership for sustainable development.
Many industries have come up with different definitions and interpretations of what is sustainable for them. For example, in mining engineering, sustainability requires international collaboration between countries, local communities, indigenous groups and companies in deciding on and coordinating mining production. From a soft law perspective, there is a need and even requirement in the mining sector for common approval, a social licence to act. A social licence can be considered to exist when a mining project has broad acceptance of society to conduct its activities. (Prno and Slocombe 2012) This requires collaboration in the responsible harmonisation of best practices, because a sustainable mineral supply chain requires vigilant resource management.

Systemic change

In order to achieve the transition towards a carbon-neutral circular economy, there is a need for systemic change in society. Changes must be made at every level and in every sector of society. Systemic change requires a complete paradigm shift. In systemic change, many aspects of the problem must be addressed at the same time, as shown in Figure 2.

When aiming to transition to a CE, changes in the industrial sectors must be made. This means integrating lifecycle thinking into material development and different design phases. In Figure 2, systemic change is presented from a carbon-neutral CE perspective. Ten different sectors of society are presented, with the enablers on the outer circles in the figure. For change to succeed, it is important to increase the level of CE competence in every sector. Different actors (i.e. countries, private companies, public organisations, etc) play a crucial role in implementing the change. Enablers are equally important because CE is based on a change of mindset, and new business models, policy instruments, data, indicators, and management approaches are needed.

The transition towards CE requires an understanding of practices in society and the resulting impacts of these practices as well as the technologies, infrastructures and institutions associated with and accessed by communities. Moreover, we need to understand the connections between these integrated system components and their dynamics. (Moloney, Horne, and Fien 2010) There are challenges whose outcomes extend beyond one geographical area, organisation, state or field of science. These wicked problems call for systemic change and different measures must be taken. The solutions for tackling a variety of problems need innovations that are created in chains and networks as well as in collaboration between different sectors of society. (Sitra 2018)

Systemic change starts with understanding the challenge we are facing, defining where we are at the moment, describing the targets we are trying to meet, and basically rethinking everything.

Promoting change – the role of awareness

The IPCC (The Intergovernmental Panel on Climate Change) Sixth Assessment Report 2022 was published in March 2022. It has a strong focus on climate change, ecosystems (including their biodiversity), and human society as well as the interactions between these. (IPCCSixth Assessment Report 2022) The main thrust of the report is that we need to act now. From this perspective, the urgency to strengthen know-how and competence in a carbon-neutral circular economy is obvious. Systemic change can only occur if professionals from different sectors of society are aware of and involved in its implementation.

Changing an economic system to circular one is not a simple task. It requires changes in, for example, organisational cultures, design, and communication. (Bertassini et al. 2021; Moser 2016; De Los Riosa and Charnley 2017) There are many barriers to change, but also drivers to promote it. The barriers and drivers have been defined from different perspectives in the literature, including built environment and mining-resource industry perspectives. The basic studies on the drivers of and barriers to the circular economy, such as de Jesus & Mendonça (2018) and Tura et al. (2019), are...
supported by more field-specific studies. Upadhyay et al. (2021) studied CE drivers and barriers in the mining industry, while Hart et al. (2019) examined the built environment. They all provide rather congruent definitions of the CE drivers and barriers, and the categorisation used in this article is based on the studies mentioned above. The major factors that affect promoting CE can be divided into social/cultural, institutional/organisational, technical, economic, regulatory, and environmental categories. The conclusion reached in a majority of the studies is that a certain factor might be both a barrier and a driver.

The global youth climate movement that started in different parts of the world has been growing over the past few years. The movement has contributed to a greater understanding of climate science and politics, and the activists of the movement are ambassadors for scientific consensus and climate mitigation. Growing awareness of climate change creates mental health issues, such as anxiety and worry about the future globally. (Ogunbode et al. 2023) However, it was found that being active helped to reduce anxiety. (Eide and Kunelius 2021)

**Summary of the literature review**

The literature review shows that the basic concepts of circular economy and sustainability were already described some forty years ago and are still usable. However, some of the meanings have changed over the years. In addition, the approach to CE varies slightly by country or field of industry. It was also found that there is not much research on CE education in the mining industry or architecture, and even less from the student’s point of view. The youth movement for climate is a new phenomenon, and there is not much research on this matter. The study was conducted with a select group of students in engineering. They were asked to answer three questions concerning barriers and drivers of promoting CE. There are not many studies concerning student views on this matter. The study was conducted with a select group of students in engineering. They were asked to answer three questions concerning barriers and drivers in writing. The categorisation of the collected data was based on earlier research. The materials and methods used in this article are presented below in Figure 4.

A case-study approach was selected because it is suitable for small-scale, intensive research that focuses on social phenomena and when observation is done within a particular group instead of between groups. (Swanborn 2010)

In Case study I, the research question was: ‘How to implement and integrate circular economy teaching in the national education system’. A ‘learning by doing’ research approach was used. This involves having people explore different possibilities and learn from their experiences. (Bruce and Bloch 2012) In Finland, the students are encouraged to learn by doing, and the same method was used in this study. (Learning together. 2020. Website) The data was collected through interviews and group discussions. Teaching development was done bottom-up in collaboration with the teachers. The collected data was used in different phases of the development process.

Case study I was part of the Finnish Innovation Fund Sitra’s work with circular economy, which started extensively in 2015, and the data was collected during the project. The first goal was to create a CE roadmap for Finland. The roadmap was published in 2016 and the updated version in 2018. Originally intended to run for two years, the CE project was extended to seven years. (See Figure 5)
In the Case study II, the research questions were: ‘What do university students studying in a technical field perceive as barriers to and drivers of the circular economy?’ and ‘How do university students studying in a technical field see their role in promoting the transition towards a carbon-neutral circular economy?’ The research data was collected by means of a questionnaire. The questions were open-ended, and the questionnaire was used to collect data on the respondents’ opinions concerning circular economy.

**Results**

**Case study I. Implementing circular economy in teaching in Finland**

The mission of Sitra’s circular economy work was to show different perspectives on sustainability and introduce CE as a solution to every sector of society. One part of Sitra’s CE work was an education programme, because the competence level for CE in Finland had to be raised to achieve the sustainability targets, such as climate neutrality. The programme was based on visits to schools and educational institutions made in 2016, where Sitra’s experts talked with teachers working at various levels of education. The network to contact was already there when the programme was launched in 2017. The timetable of the programme is presented in Figure 6.

In order to achieve the objective, sustainability, it is vital to find a role for everyone, ranging from professionals in different fields to schoolchildren. It is not enough to simply have environmental managers or sustainability experts in different organisations to oversee the transition towards sustainability, because it is everyone’s responsibility. CE skills and knowledge look different in legislation, business, construction, chemistry, mining, behavioural sciences, health care, pharmacy, food production, etc. (Figure 7, A phase 1). Therefore, one of the targets was to bring CE in the Finnish education system at all the levels from early childhood education to higher education, and adult education.

The aim of the education programme was to support teachers and schools in creating educational materials on CE from different perspectives (Figure 7, A phase 1). The education sector has a key role in creating knowledge and understanding of the CE in the different sectors of society and in supporting a transition towards a carbon-neutral circular economy.

The requirement was the same as in a multidisciplinary research project combining different perspectives in the educational content. In order to develop ideas, Sitra held workshops, after which project plans were further developed. Finally, after the development process, the education programme consisted of 21 consortium projects funded by Sitra. The themes of the CE-related courses at each level of education are listed in Figure 7 (A phase 2). During the programme there were regular events held for teachers and organisations. In these events, experts from different fields delivered presentations to give teachers new perspectives on the future and teaching.

The result of the project was a plan how to bring CE teaching in the curriculum/national education system. These experiences and lessons learned, presented in this article, can be used in other countries in the development of CE education and integration of circular economy education into the national education system.

**Case study II. University student interviews**

As the Sitra project proceeded, it was considered important that information on the current status of circular economy knowhow and competences at the university level be collected. The project leader, Dr. Nani Pajunen, gave five lectures on the
CE, three in Finland and two in Canada, during the months of September and October 2018. Data was collected at the end of the lectures. The groups in Canada were mining and mineral processing engineering students at the University of British Columbia (UBC). In Finland the participants were architectural students from Aalto University and Yale University (USA), and students in an environmental specialist course at the University of Helsinki (Table 2) Answering the questions was voluntary and practically all participants returned the questionnaire. Any personal details, such as name, age, gender, ethnicity, etc. were not collected. The students were told the purpose of the survey in advance and the consent to use the collected data was given by the students when they submitted their responses. University of British Columbia Ethics office has given a permission to use the data.

A case study research approach was used, with the focus being on examining how the circular economy barriers and drivers is perceived by individual university students.

The students were asked three questions:

- When striving to become a CE society, what are the most important drivers?
- When striving to become a CE society, what are the most important barriers?
- How do you see your own role in this change?

The free-form responses were written down on paper and later transcribed. The responses varied from single words to five-line sentences. For the purpose of analysis, the responses were read several times. In the first phase, sentences, parts of a sentence or single words were divided into units, which were then categorised under 'Most important barriers' and 'Most important drivers'. There was a total of 345 units: 162 units in the 'Most important barriers' category and 183 units in the 'Most important drivers' category. (Table 3) In both groups the units were categorised under the same headings: 'Information and education', 'Environment-related', 'Concrete impactors' and 'Policies'.

In the second phase, the units were divided into smaller groups derived from the data. The categorisation followed an abductive
approach. The data analysis was conducted by textual coding and looking for emerging categories in the data. These were then analysed in the context of the previous studies. (Timmermans et al. 2012). The emphasis of the drivers and barriers between the four main categories and no answer is presented in Figure 8.

Education and information were seen as major drivers in transition towards circular economy. When the drivers and barriers are compared it is obvious that information and education plays a big role in promoting CE and the lack of information is hindering it. Environment-related factors are seen more as drivers than barriers (see Figure 8). The drivers include awareness of material depletion and climate change as well as the urge to act. On the other hand, ‘Too many people ignore environmental problems or feel that their own contribution is insignificant’. (CE-2018-10). Awareness of environmental issues has increased, and the companies have noticed that being environmentally-friendly benefits the business. Environment-related barriers included lack of motivation, global instability and even desperation. ‘It feels difficult to do anything concrete because it feels that my contribution doesn’t matter’. (CE-2018-03)

The most important driver towards CE is to increase knowledge and understanding of environmental issues and solutions to environmental problems (see Figure 9). Accordingly, peoples’ attitudes and degree of knowledge and know-how is a major barrier. The challenge is that information and education are not available to all.

The category ‘Concrete factors’ included economic factors and technology. Economic factors have a major impact on hindering development of a CE (see Figure 10): ‘Another barrier is the fact that humankind is constantly pursuing economic growth on every level’ (CE-2018-40). Lack of sanctioning, poverty, greed and the constant pursuit of economic growth were mentioned several times as barriers. Economics was seen more often as a barrier in the sense that changing from old production methods to new ones requires financial investments and companies are not very keen on making them. The students considered technology as a driver which holds potential for providing solutions in targeting the CE. ‘… not the technology itself, but the awareness of people to accept the new tech or devices’. (CE-2018-44).

Regulatory issues (policies and laws) could be both driver and barrier, but not a major one. ‘Politics and economy must change in a total manner first’. (CE-2018-92).

When the students were asked about their own role in the change, they said that they have an opportunity to make a difference both as individuals and as future professionals: engineers and architects. As an individual, they have only a small impact as consumers and role models. However, as professionals, they will have much better opportunities to influence policies and work culture. The students had clear visions of how they can act effectively, economically and in an environmentally-friendly way. They believe that, serving in an expert capacity, they have better opportunities to educate others and act as ambassadors of CE. ‘Bringing questions of circular economy into construction with the construction sectors and clients’ (CE-2018-100) and ‘To be able to recycle most of the waste at mines’ (CE-2018-78).

### Experiences with integrating circular economy into education in Canada

The University of British Columbia (UBC) became the first university in Canada to adopt a sustainability development policy in

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**Table 2. Overview of interviews.**

<table>
<thead>
<tr>
<th>Participants</th>
<th>Organisation</th>
<th>No of answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular and bioeconomy students</td>
<td>FRUSH, Finland</td>
<td>18</td>
</tr>
<tr>
<td>Environmental specialist course</td>
<td>UH, Finland</td>
<td>24</td>
</tr>
<tr>
<td>Aalto + Yale architecture students</td>
<td>Sitra, Finland</td>
<td>14</td>
</tr>
<tr>
<td>Mining engineers</td>
<td>UBC, Canada</td>
<td>18</td>
</tr>
<tr>
<td>Mineral processing engineering</td>
<td>UBC, Canada</td>
<td>29</td>
</tr>
<tr>
<td>ALL</td>
<td></td>
<td>103</td>
</tr>
</tbody>
</table>

**Table 3. Division of the units into the two categories.**

<table>
<thead>
<tr>
<th>Most important barriers</th>
<th>Most important drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>162</td>
<td>183</td>
</tr>
<tr>
<td>47 %</td>
<td>53 %</td>
</tr>
</tbody>
</table>

**Figure 8.** Comparison between drivers and barriers on each answer group.
1997. It was also the first university to open an official sustainability office devoted to campus sustainability. At UBC, sustainability themes are integrated into teaching, learning and student engagement activities and enhanced. (Personal communication with Prof. Susan Nesbitt. 2021) During their degree programme, mining engineering students in the Faculty of Applied Science (APSC) are required to take several courses, whose content is related to the sustainability of the engineering design process. The courses for mining students are offered during the first, third and fourth year, and are designed to introduce the concept of sustainability in the context of mining industry.

In recent years, there has been increased support from the Government of Canada for circular economy ambassador programmes. A programme launched in 2021 was organised in coordination with Plastic Oceans Canada in British Columbia. 400 high school students from 15 schools participated in collecting waste from shorelines and diverting waste from landfills. The goal of the programme was to effect change through educating younger generations on the importance of the CE. The students were collecting data on what type of waste they were finding. The programme also provided material for curriculum development.

**Summary of the results**

To change the direction of the progress of climate change and the sustainability crisis everyone must know the means of sustainable consumption. The problem is that the decisions needed to change the system from the current linear consumption system to a circular one have not been made. In this study, we found that one of the reasons for this is a lack of knowledge, which is something that can be changed by means of education.

This study shows that planning CE education and creating a curriculum according to the plan is possible when the process is supported by grassroot actors, i.e. teachers. Education on CE should be started at the ground level to build in-depth
knowledge and understanding. In the current situation, CE teaching should be implemented at all levels of education, regardless of whether the students have any basic knowledge of CE. This is especially important for experts in the material production fields, such as mining industry. The experts in different fields should be aware of the complexity of the problems as well as the solutions. The example from Canada proves that teaching CE at university gives the students tools to understand what CE is and what it would mean in their own field. CE has been taught at UBC for more than two decades, and the results of the education can be seen in the answers of the engineering students.

**Discussion**

There is a worldwide need for systemic change and even more urgent need to start implementing such change towards instituting a circular economy system. A big challenge in transitioning is the lack of knowhow and, as a result of this, a lack of tools and actions. This is why every single member of society needs to increase their level of competence in CE. The world is constantly changing, and education needs to respond to these changes. When society moves towards a carbon-neutral circular economy, the education sector plays a key role in implementing CE teaching and providing up-to-date information.

We are living in the fourth industrial revolution. It overlaps the third industrial revolution, which is characterised by a fusion of technologies and the blurring of the lines between the physical, digital, and biological spheres. The fourth industrial revolution is more cyber-physical and evolving rapidly, affecting more or less all industries. Mobile technology makes it possible for people across the world to connect, and artificial intelligence enables combining technical applications in different ways, such as with our bodies or the buildings we inhabit. (WEF, 2016. Website) This new era brings new possibilities as well as requiretuings for teaching and education. However, the sustainability crisis is still upon us. The solution does not lie in technology, but in behaviour. It is up to us whether we are able to tackle the crisis or not. Indeed, we need new technologies in the future, but technology is not the solution to this crisis.

Technology and materials around us comprise our social environment and culture. People create the material world and are shaped by it, and this varies between different cultures. CE is not just about repairing broken appliances or clothes. It means a change in the everyday relationships that humans have with materials, which is precisely why replacing concrete things with dematerialised services is difficult. (Hobson, 2020)

The systemic change has to be ‘custom-made’, meaning that education and information has to be tailored to the culture, whether we are talking about societies or companies. The transition towards sustainability can succeed only if all countries and people are part of the change and play a role in making it happen. Each and every individual also has the right to be part of this transition. The world is constantly changing, and education needs to respond to these changes – this also includes CE education. The education sector will constantly confront greater challenges that it will have to address. ‘My role is to develop science to make more things circular. A key component is communication, which can be improved by a better education’. (CE-2018-59)

It is important also to educate specialists, people who focus and deepen their knowledge in their own fields. Furthermore, they must also be able to work with experts in different fields and on multidisciplinary teams in order to come up with sustainable solutions. The systems are complicated as are, in many cases, the solutions. Specialists in different fields have been trained to deal with complex matters. The transition towards circular economy requires collaboration between different sectors and between different experts. Without a novel approach to collaboration, it is more difficult or even impossible to truly rethink our way of doing things and ultimately make changes. (Pajunen and Mäkikoskela, 2017)

The first target in Finland’s CE education programme was to focus on today’s school pupils and university students. However, this is not enough, as there is an increasing need to involve everyone in working life to increase competence in CE. The aim now is to promote the goal of making us all CE professionals. Employers will play a major role in achieving this goal. In earlier studies, it has been shown that a stronger focus on sustainability and CE in society, including different sectors of society and different perspectives, requires deeper understanding and knowledge. (Pajunen, 2015)

The groundwork of the project included interviews with teachers as well as mining engineer and architect students. There is not much earlier research on implementing CE in school curricula. When teachers were engaged and the project succeeded, ministry-level planners and decision-makers were also engaged with the project. For this article, university students were asked about the main barriers to and drivers of CE as well as their opinion on how they could act as the agents of change in promoting it. The results show that the students were able to recognise the drivers and barriers very well. Furthermore, they are ready and more than willing to act once they start working as mining engineers or architects, as they would have greater opportunities for promoting systemic change in order to enable CE.

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**Table 4. The summary of results.**

<table>
<thead>
<tr>
<th>Research question</th>
<th>Actions and research method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to implement and integrate circular economy education in the national education system?</td>
<td>Circular economy education programme 2017–2019 Learning by doing, learning from experiences resulting directly to actions</td>
<td>The model how to integrate circular economy courses in all the levels of the national school system</td>
</tr>
<tr>
<td>What do university student study in a technical field perceive as barriers to and drivers of the circular economy?</td>
<td>University students’ interviews 2018 An interview study (survey) as a qualitative research method</td>
<td>The students’ current view of the drivers that promote circular economy or the barriers that prevents economy</td>
</tr>
<tr>
<td>How do university students studying in a technical field see their role in promoting the transition towards a carbon neutral circular economy?</td>
<td>University students’ interviews 2018 An interview study (survey) as a qualitative research method</td>
<td>The students’ current view of their own role in the transition towards a carbon neutral circular economy</td>
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</tbody>
</table>
As a result, based on the Sitra’s CE education programme, we collected a list of actions for integrating CE in the national curriculum and school system. (Table 4)

The questionnaire data was collected in the autumn of 2018. Nevertheless, in the three years after the data was collected, there have been unforeseen global developments that have affected the global economy, international politics, and everyday lives of people all over the world. The global pandemic as well as security crisis in Europe caused by the war in Ukraine have radically changed the state of the global economy. It has affected the production of raw materials and the trade with certain countries has likely changed permanently. The value of CE and recyclability of materials is obvious because it can increase the security of supply and ensure production through the use of secondary raw material sources.

There were also limitations in the questionnaire. The focus group was not pre-selected, and the background information was not collected. This affected the analysis, and no strong contentions regarding the generalisability of the identified barriers and drivers can be made. On the other hand, the results were usable in supporting the findings of other studies and developing circular economy teaching in Finland.

Conclusions

In this article, we have pointed out the importance of education and individual contributions in the transition towards a carbon-neutral circular economy society. In the two case studies presented, we have shown that there is a demand for circular economy education. Based on the experiences in Finland, it is possible to integrate CE education at different levels of the education system. The Finnish model (See Table 5) cannot be exported as such, but it is possible to adapt it to different education systems, taking into account different structures of society in different countries and cultures.

The transition to a CE starts with enabling systemic change. It is difficult but not impossible, and the change should be started from the ground up by educating people. Education and enlightening people are key elements in changing consumption habits in the long run. When people understand why CE is necessary and how it benefits people, they are more willing to promote it. As one of the interviewed students put it: 'For example, well-educated and informed citizens can prevent themselves from being ill and a well-educated person also knows what is harmful for our environment and nature'. (CE-2018-56).

Future research should dive deeper into how we can export working education models (e.g. the Finnish model) to other countries and cultures. Finally, it is important to continue academic research on changing behaviour and how to affect the attitudes of individuals who are still increasing their consumption and how to change cultural habits and values to achieve a real transition towards sustainability.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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