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Towards an Education for the Circular Economy (ECE): Five Teaching Principles and a Case Study

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ABSTRACT

The circular economy (CE) concept is seen by many as a novel pathway to sustainable development. A few scholars have started outlining educational approaches and tools that lecturers can use to accelerate the transition towards a circular economy. This paper aims to contribute to this nascent body of literature on education for the circular economy (ECE) by describing and critically discussing a course designed to introduce undergraduates to the CE concept. The course design adopted the pedagogical principles of constructive alignment and problem-based learning, as well as interactivity, non-dogmatism, and reciprocity. Seven exercises were developed for it: a drill game, buzzword bingo, a teardown lab, an eco-industrial park simulation, policy instruments, a circular party and circular futures. The course received an excellent rating by the participating students (with feedback collected for each module at the end of every module as well as for the entire course at the end of the course). The ECE approach outlined in this paper can be utilized and further developed by lecturers keen to incorporate the CE concept into their teaching. Overall, this paper hopes to encourage lecturers to share additional best practices regarding CE teaching with the intention of fostering a discussion on how to best approach ECE.

1. Introduction

The circular economy (CE) can be defined as a concept whose implementation entails reducing the consumption of raw materials, designing products in such a manner that they can easily be taken apart and reused after use (eco-design), prolonging the lifespan of products through maintenance and repair, using recyclables in products, and recovering raw materials from waste flow (van Buren et al., 2016). The concept has emerged as a political vision around the world in recent years. It is a policy priority in China (Dajian, 2008; Liu and Bai, 2014) and in Europe with the European Commission (EC) having adopted its Circular Economy Package in 2015 (EC, 2015) and national governments, such as the Dutch (Government of the Netherlands, 2016), the Welsh (Welsh Government, 2014) and the Scottish (ZWS, 2016), also embracing the CE with dedicated initiatives. The concept's proponents claim that the CE offers a novel pathway to sustainable development, with sustainable development defined via the triple bottom line concept as simultaneously accomplishing economic performance, social inclusiveness, and environmental resilience to the benefit of current and future generations (Elkington, 1997; Geissdoerfer et al., 2017).

Contributions from a variety of stakeholder groups are needed to enable a transition toward a CE. The role of the private sector has been particularly highlighted in recent years (Bocken et al., 2017; Heshmati, 2015; Jiang and Zheng, 2014; Kirchherr et al., 2018). Some even argue that the emphasis on the role of businesses as well as on economic performance constitutes the novelty of the CE when compared to the sustainable development concept (Lewandowski, 2016; Urbinati et al., 2017). Meanwhile, a stakeholder group that has received little attention so far are lecturers in higher education (Ellen MacArthur Foundation, 2017a; Kopnina, 2017). This negligence is surprising, considering that it has been repeatedly argued that "education is the key intervention for bringing change in knowledge, values, behaviors and lifestyles […] required to achieve sustainable development" (Pandey and Vedak, 2009, p. 3; see also Berryman and Sauvé, 2016).

While "higher education is nowhere near optimizing its contribution to sustainability" (Johnston, 2007, p. 48), universities have progressively incorporated sustainability education in their curricula since the early 1990s (Anderberg and Hansson, 2009; Johnston, 2007). Environmental education, a predecessor of sustainability education that highlights sustainable development's environmental pillar, has even been part of university curricula at least since the late 1970s, with the MSc in Environmental Technology at Imperial College London launched in 1977, for instance (Imperial College London, 2017). The rise of sustainability education has resulted in a scholarly field of study on

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sustainability education, named "education for sustainable development" and abbreviated as ESD throughout this paper[1], which examines these efforts with the intention of improving sustainability education (Wu and Shen, 2016). It can be assumed that the CE, as an allegedly novel pathway to sustainable development and thus only a partial subset of ESD, requires education beyond ESD.

This paper aims to contribute to the nascent body of literature on teaching the CE in higher education institutions (with 'education for the circular economy' abbreviated 'ECE' throughout this paper) by describing and critically reflecting upon a CE introductory course delivered to undergraduate students at Utrecht University (The Netherlands) in, 2017. The course design was based on the pedagogical principles of constructive alignment and problem-based learning as well as interactivity, non-dogmatism, and reciprocity. The course also featured various novel CE exercises, such as a teardown lab and an eco-industrial park simulation.

The remainder of this paper is organized as follows. Section 2 presents a literature review of ESD, education for the CE, and the teaching and learning approaches and core principles that also informed the design of the CE introductory course described in this paper. Section 3 provides an overview of the course 'The Circular Economy: An Introduction' and the methods adopted to assess the course and its effectiveness. Section 4 presents the course structure and content, as well as the results of its evaluation by the students. Finally, Section 5 critically reflects upon this course and a conclusion is provided in Section 6 of this paper.

2. Literature review

The potential role of education in the transitioning of societies toward sustainable development was initially highlighted at the first Earth Summit in Rio de Janeiro in 1992, which is also credited (jointly with the 1987 Brundtland report) to have coined the term "sustainable development" (Anderberg and Hansson, 2009; Fulton, 2012; Palmer, 1992).[2] The role of education was again brought to the forefront of international attention via the UN World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 as well as at the second Earth Summit in 2012 in Rio de Janeiro (Anderberg and Hansson, 2009; Broecks et al., 2016). UNESCO even declared 2005–2014 as the UN Decade of Education for Sustainable Development (UNESCO, 2014). The scholarly field that has emerged on ESD is indicated, among other things, by journals entirely dedicated to ESD, such as the *Journal of Education for Sustainable Development* (JESD, 2017) and the *International Journal of Sustainability in Higher Education* (IJSHE, 2017).

These summits, the ESD decade mentioned above, and the dedicated scholarly journals have enabled some integration of ESD. For instance, much of ESD outlines the triple bottom line as an operationalization of sustainable development (Elkington, 1997; Figueiró and Raufflet, 2015; Wu and Shen, 2016). However, this concept is frequently interpreted differently by different ESD scholars (Reid and Petocz, 2006; Wu and Shen, 2016). Hence, some have argued that the ESD field is only consistent on paper at first glance, whereas it is lacking conceptual consistency in reality (Anderberg and Hansson, 2009; Berryman and Sauvé, 2016). This lack of conceptual consistency is certainly also a risk regarding education for the CE, considering that CE as a term is highly contested in the current sustainable development discourse with Kirchherr et al. (2017) finding, for instance, that there are as many as 114 different CE definitions currently used by scholars and practitioners. While some of the existing definitions mostly focus on recycling, others go as far as including ten different strategies to achieve a CE

(*e.g.* Potting et al., 2017; Reike et al., 2018).

More than 100 articles per year have been published on ESD ever since 2013[3], indicating a mature field of study (Figueiró and Raufflet, 2015; Wu and Shen, 2016). However, Huckle (2012, p. 856) writes that "funding for ESD is now more difficult to find", while Jickling (2016, p. 128) concludes that "[ESD has] had little impact", which may be interpreted as an indication that ESD as a field also struggles. This may be caused by the underlying term "sustainable development". For instance, Engelman (2013, p. 3) writes that "we live today in an age of 'sustainababble', a cacophonous profusion of uses of the world 'sustainable [development]' to mean anything from environmentally better to cool", while Naudé (2011, p. 352) calls it a "theoretical dream [rather than] implementable reality" and Jickling (2016, p. 128) concludes that "sustainable development does not seem to have much traction". Several terms such as "green economy", "green growth" and "circular economy" have emerged to reinvigorate the concept of "sustainable development", as argued by Kirchherr et al. (2017, p. 221), "whereas the CE concept is argued to be the one with most traction these days" (Kirchherr et al., 2017). While sometimes presented as substitutes, it is noted that many of these terms usually do not cover all aspects of sustainable development; for instance, "green economy" largely, albeit not entirely, neglects the social pillar of sustainable development (D'Amato et al., 2017).

Since ESD constitutes a mature field of study, scholars aiming to teach sustainable development can draw on many ESD studies. On the contrary, research on education for the CE is still somewhat limited, despite the overall CE literature—now with at least 850 articles published in academic journals—is vast (D'Amato et al., 2017)[4] and the CE is being introduced in many teaching programs[5] . One example of education for the CE literature is a paper by Andrews (2015), who discusses education for sustainability with a focus on the CE and design thinking. Similarly, Leube and Walcher (2017) and Pitt and Heinemeyer (2015) examine education for the CE from a design perspective. On the other hand, Knudby and Larsen (2017); Sanchez-Romaguera et al. (2016); Santasalo-Aarnio et al. (2017); Ormazabal et al. (2018) and Whalen et al. (2018), elaborate on CE education specifically tailored to engineering students. Finally, Kılkış and Kılkış (2017) describe how CE is integrated in an energy policy course, while Kopnina (2018, 2017) discusses some experiences of teaching the CE in the context of undergraduate business education. In addition to academic literature, some CE-related teaching and learning resources are also made available by various public and private organizations including the Ellen MacArthur Foundation (2018), Finnish think tank Sitra (2018), and the EU-funded project Three C (2015).

Extant literature on education for the CE is grounded on a variety of theories of learning and teaching, which find expression in a wide-array of teaching activities. Most proponents of CE courses and curricula in higher education adopt outcomes-based teaching and learning

[1] This field of study is also called "education for sustainability," abbreviated as EFS by Cortese (1999), or "sustainability education," abbreviated as SE by Lozano et al. (2015). The acronym ESD is employed throughout this paper since it is the most frequently used term based on the articles consulted for this study.

[2] The role of education as playing an important role in fostering environmental protection and conservation was formally recognized at an international level by the Stockholm Conference in 1972 (D'Amato et al., 2017).

[3] A Scopus search was conducted to retrieve relevant data with the search function employed reading: TITLE-ABS-KEY ("education for sustainable development").

[4] D'Amato et al. (2017) developed their set of 850 CE articles by searching for "circular economy" via the search engine *Web of Science* with the starting date for their search set as 1990 and no end date specified (their article was accepted by *Journal of Cleaner Production* in early September 2017).

[5] The Ellen MacArthur Foundation, possibly the most visible and influential proponent of the CE (Lieder and Rashid, 2016), has attempted to comprehensively map CE teaching worldwide. According to its latest report (Forslund et al., 2018), 138 higher education institutions currently provide CE learning offerings as part of their programs in the fields of sustainability, engineering, business studies and design.

approaches, such as constructive alignment or some form of problem-based learning (Biggs and Tang, 2011; Duch et al., 2001). Sanchez-Romaguera et al. (2016, p. 4), for example, promote "the use of contextual, active, multidisciplinary, collaborative and cumulative approaches to learning", whereas Whalen et al. (2018) advocate for experiential learning through the use of a serious game that supports holistic and transdisciplinary thinking for a CE. The ESD literature as a superset (at least partial) of the education for the CE literature also offers a number of suitable CE teaching core principles that were eventually included in the design of the course analyzed in this paper.

2.1. Interactivity

Zenelaj (2013, p. 223) argued that a fundamental belief of ESD would be taken from "Confucius [who] said 'I hear and I forget. I see and I remember. I do and I understand,'" with participatory teaching methods thus seen as a "common denominator" in ESD (Wu and Shen, 2016, p. 634; see also Barth et al., 2007; Juárez-Nájera et al., 2006; Kevany, 2007). This rebuttal of traditional lecture classes in favor of interactivity was thus adopted as a core design principle for the CE introductory course described in the next sections. This principle also resonates with Kopnina (2017), who describes a CE course that entailed students helping 17 different companies to increase the circularity of their business models – an example of interactive teaching.

2.2. Non-dogmatism

Non-dogmatism has been highlighted by several ESD scholars, such as Velazquez et al. (2005) and Figueiró and Raufflet (2015), as a core design principle. Non-dogmatism requires "not to become overly committed either to the optimistic [CE] win-win scenarios that might be unrealistic or to all-down skepticism" (Kopnina, 2017, p. 21). Regarding environmental education, already Biswas and Biswas (1982, p. 128) noted "a tendency to introduce certain dogmatic ideas", which would require rebuttal. This can also be a risk regarding education for the CE, considering that CE as a concept is often described with over-enthusiastic tones. For instance, *The Guardian* contended that "[CE] inspires young people to change the world" (Perella, 2015). Introducing both the strengths and challenges of the CE concept to enable students to critically reflect upon CE was thus also adopted as a core design principle for the course described in this paper. Again, this resonates with Kopnina (2017, p. 8), who also aims for the "development of critical thinking" in her CE teaching.

2.3. Reciprocity

A third design principle identified in the literature is reciprocity, which refers to continuously incorporating students' feedback into a course. This can create tension with the previous two design principles if students demand to move away from interactivity and/or non-dogmatism. To avoid this tension, this third principle was chosen as the core guiding principle of the course, reflecting the lecturer's view that students taking a course know best how to further improve it. The collection of feedback that was conducted for each module of the course is also grounded in this principle.

3. Background of the course and its assessment

Describing a specific course is the most common methodological set-up in ESD papers (Wu and Shen, 2016). This approach is grounded in the belief that ESD "can be improved through systematic review of specific experiences" (Geng et al., 2009, p. 978), a belief also held by the authors of this paper. The CE introductory course presented here was delivered by the first author of this paper in early 2017 as an elective in the honors program within the bachelor's programs of the Faculty of Geosciences at Utrecht University in the Netherlands. Honors education is intended for the most talented and ambitious students at the university, and it is undertaken in addition to the regular course load within specific bachelor's programs. During the relevant period, 47 bachelor's students enrolled in the course. Of these bachelor's students, 44% were from "Human Geography and Planning" (Universiteit Utrecht, 2017b), 18% from "Earth Sciences" (Universiteit Utrecht, 2017c), 18% from "Environmental Sciences" (Universiteit Utrecht, 2017d), 9% from "Science and Innovation Management" (Universiteit Utrecht, 2017e), and 12% from miscellaneous programs. The wide variety of disciplines represented in the course was welcomed by the lecturer since CE is such a multidisciplinary topic that it was assumed that student inputs from various disciplines throughout the course would only strengthen it. Students taking part in the course could be from the first, second, or third year of their respective bachelor's programs.

To maximize insights regarding the specific teaching approach adopted, significant amounts of feedback were collected throughout the entire course from the course participants. First, feedback was collected at the end of every module with three questions posed to participants each time. These were as follows: (1) How did you like this module?[6] ; (2) What could be improved regarding this module?; and (3) What did you particularly like about this module?[7] Furthermore, a formal evaluation was conducted at the end of the course by means of the official evaluation form of the Faculty of Geosciences, Utrecht University. This form consists of statements/questions such as "I give the course an overall mark of …"[8] or "What are, in your opinion, the three best points of the course?[9] ." The formal evaluation form is available upon request. The module evaluations depicted in Fig. 5 of this paper were taken from the input provided by students via PresentersWall, whereas the overall evaluation results of the course and the results presented in Fig. 6 were obtained from this formal evaluation. Qualitative feedback from the students shared in Section 4.2 of this paper was mostly gathered via PresentersWall.

It was explained to the students in the first module of the course that feedback was collected at the end of every module instead of just at the end of the final one (which is the standard procedure at the university of the authors of this paper) to maximize the lecturer's learning about how to improve the course. It was further explained that the feedback provided would be utilized in a reflective piece on the course that would be submitted to this journal. The students agreed with this. All feedback was provided anonymously to ensure that students could share their views frankly with the lecturer.

Prior to joining academia, the lecturer was with McKinsey & Company, a consultancy closely intertwined with the Ellen MacArthur Foundation, and he had various practical touchpoints with the CE during this time. This experience was reflected in the course via various anecdotes shared throughout it. The scholarly literature on the CE was largely unfamiliar to the lecturer prior to teaching the course, which resonates with Velazquez et al. (2005, p. 386), who write that many "professors are learning and teaching about sustainability at the same time" (see Brumagim and Cann, 2012; Persons, 2012; Wu and Shen, 2016). However, the lecturer had a multi-disciplinary background (*i.e.* economics, political science, business administration, and geography), which helped him master a multifaceted concept like the CE. The lecturer had no teaching commitments in the months prior to teaching the described course and could thus invest considerable time to familiarize himself with the relevant literature, which then also informed the set-up and contents covered in the course. Guest speakers knowledgeable

[6] The students were asked to respond to this question on a scale ranging from 1 ("Very unsatisfied") to 10 ("Very satisfied").

[7] Questions (2) and (3) were open-ended questions.

[8] The students are asked to respond to this question on a scale from 1 ("Very unsatisfied") to 10 ("Very satisfied").

[9] This is an open-ended question.

on specific aspects of the CE the teacher was not so proficient in (*e.g.* eco-industrial parks) were also invited to give talks, thus bringing added value and credibility to the course. Finally, two field trips were organized to provide the students with complementary insights on how CE is implemented by practitioners in real-life.

4. "The circular economy: an introduction"

4.1. Course overview

The purpose of the course was to provide a holistic introduction to the CE. Students were largely unfamiliar with the CE concept prior to this course[10], whereas the CE is researched by scholars in all disciplines represented by the four undergraduate programs the students were enrolled in, as outlined in Section 3. Human geographers have taken interest in the CE concept as a vision to manage interactions between the environment and economies (Kopnina, 2015a; Rochman, 2016); earth scientists are most interested in the technical aspects of CE implementation at the micro level (Sauvé et al., 2016); environmental scientists view the CE as a promising paradigm to reduce companies' environmental impacts (de Jesus and Mendonça, 2018d; Kirchherr et al., 2017); and innovation scientists have started viewing the CE as a systemic innovation (de Jesus and Mendonça, 2018d; Kirchherr et al., 2017). The CE concept is thus of direct relevance to the main specializations of the students who took the course, whereas differing aspects of the concept tend to be highlighted by different disciplines. The course design strived to accommodate the diverse interests and disciplinary background of the students, which well embodied the inherent multidisciplinary nature of the CE topic.

The course was taught over eight modules (90 min each), and its structure (depicted in Fig. 1) was presented in the very first module. At the core of this structure is the spatial differentiation of CE, a differentiation taken from Fang et al. (2007, p. 316), who wrote that "at the macro-level, the development of a CE emphasizes adjusting industrial composition and structure. … At the meso-level, … [CE emphasizes] applying industrial ecology concepts. … At the micro-level, the CE will ensure that by-products are identified in individual enterprises and used effectively". The course was started with an introductory lecture. Then, three lectures with a variety of interactive elements on the micro, meso, and macro levels were conducted (framed as the "applied theory" part of the course). After that, excursions were carried out (framed as the "practice" part of the course), which showcased the theory taught to the students in practice. The course closed with a wrap-up lecture. The lecturer attempted to spark a critical discussion regarding the CE in all modules.

It is noted that students were largely unfamiliar with teaching based on interactivity prior to taking this course. Indeed, several students commented that the approach of the course was "really different" to any course they had ever taken before. Courses in the respective bachelor's programs of the students rely mostly on traditional lecture classes, whereas group work is also used in some programs. However, this is usually not in-class group work.

In designing the course "The Circular Economy: An Introduction", an outcome-based teaching and learning approach (Biggs and Tang, 2011) was adopted. This is based on the explicit articulation of intended learning outcomes (ILOs) that identify what students are expected to know and be able to do after completing a course (Au and Kwan, 2009; Pang et al., 2009; Tam, 2014). Building on Bloom's revised taxonomy (Anderson and Krathwohl, 2001), the ILOs of the course (Table 1) were designed to activate different cognitive levels of learning and foster a deep (*vs* superficial) approach to learning (Jackson, 2012).

The course used the principle of 'constructive alignment' (Biggs and Tang, 2011) to ensure that teaching/learning activities and resources, as well as assessment tasks, were systematically aligned to the course ILOs (Table 2). The teaching/learning activities proposed in the "applied theory" part of the course (Fig. 1) were grounded in a 'problem-based learning' (Duch et al., 2001) approach (*e.g.* working co-operatively in small groups, developing solutions to complex real-word problems) and were devised as opportunities for formative feedback (*i.e.* feedback provided by the teacher during learning; *e.g.* telling students how well they were doing and what they could improve) (Biggs and Tang, 2011). The readings selected for the course ranged from classics on the circular economy, such as Boulding (1966), to very recent (and critical) literature on the topic, such as Skene (2017) (reflecting the second course design principle adopted—non-dogmatism). Knowledge of the readings was required for the various assessment tasks undertaken throughout the course, with all assessments being completed in class, mostly in the form of presentations that allowed the teacher to judge (with the help of rubrics) if and how well students' performances met the relevant intended learning outcomes.

4.2. Course content

The first module was intended to ensure that students would understand the guiding principles and aims of the CE concept, which included enabling students to relate it to neighboring concepts (*i.e.* ILO 1, Table 1). A drill game was played at the very beginning as an ice-breaker. This game is an exercise that asks students to model a company's profitability in a linear and circular scenario. For this game, students were specifically asked to model the profitability of a Chinese manufacturer of drills both in a linear economy (status quo) and circular economy (recycling) scenario. The game highlighted "recycling" to students as one core aim of the CE (Ellen MacArthur Foundation, 2016; Lieder and Rashid, 2016) and taught them that one purpose of the CE (from a company perspective) is to increase profitability (Ellen MacArthur Foundation, 2016; Lieder and Rashid, 2016). A second exercise in this first module, coined "buzzword bingo," asked students to relate the CE concept to the concepts of the green economy (Chertow, 2000), industrial ecology (Vanaga and Blumberga, 2015), and biomimicry (Vanaga and Blumberga, 2015).

Prior to this, the 9R framework, developed by Potting et al. (2017), was outlined as the how-to of the circular economy[11] and the triple bottom line as its main aim (Elkington, 1997; see also Ghisellini et al., 2016; Lieder and Rashid, 2016). In line with the non-dogmatism course design principle, it was explained to the students that this view regarding the CE was only one of many. Feedback provided by the students at the end of this module indicated that they would have liked to learn more about why the CE concept is currently adopted by various governments.

This feedback was incorporated, reflecting the third outlined design principle of the course (*i.e.* reciprocity), in the course's second module, which was the first module on the micro-level of CE. In the beginning of the module, reasons for the Dutch government to adopt the CE were outlined and critically evaluated. This resonates with Kopnina (2017, p. 21), who argues that students learning about the CE must also be taught "about larger demographic and societal challenges" that induce the CE. Meanwhile, the focus of this second module was on eco-design. This was inspired by Andrews (2015), who argues that eco-design needs to be at the core of CE teaching. A teardown lab was chosen as the format to explore eco-design and achieve ILO 2 (Table 1). A teardown lab is an exercise with two sequential elements: an application element, where a product is taken apart by the exercise's participants, and an ideation element, where participants brainstorm how this product could be

[10] Students were asked via the application PresentersWall during the first module of the course regarding their level of familiarity with CE; 78% responded that they were "entirely unfamiliar" or "largely unfamiliar" with CE.

[11] The sharing economy concept was also presented to the students as part of the 'Rethink' strategy.

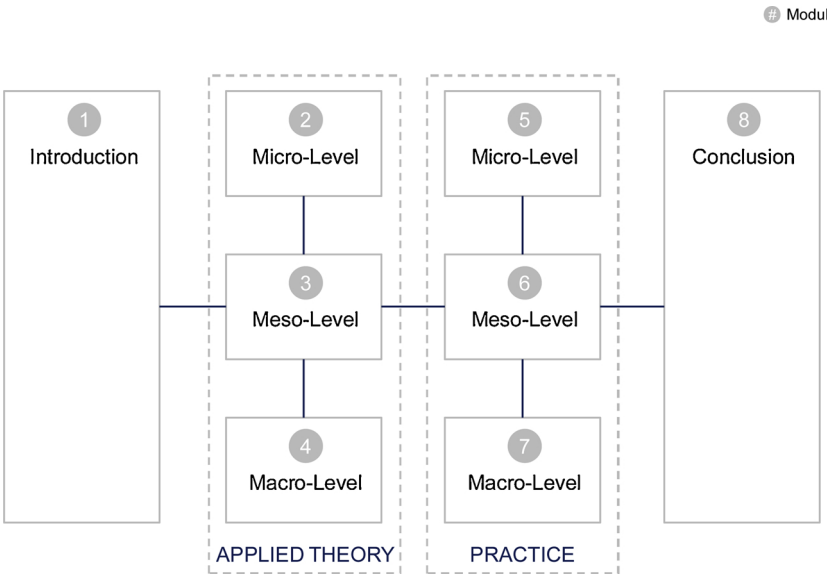

Fig. 1. Course structure for the course 'The Circular Economy: An Introduction'. Source: Adapted from Potting et al. (2017, p. 5).

Table 1
Intended learning outcomes (ILOs) of the course 'The Circular Economy: An Introduction'.

After completion of this course, students will be able to:
1 Understand the guiding principles of the circular economy and relate it to neighboring concepts
2 Investigate what it takes to create products that are easy to repair, refurbish, remanufacture, repurpose, recycle or recover
3 Explain drivers and barriers for businesses to cooperate towards a circular economy
4 Gauge the macro-systemic effects of the transition towards a circular economy
5 Critically reflect upon the circular economy concept

redesigned (Alwi et al., 2014; Rosano and Biswas, 2015). Accordingly, students were first tasked with disassembling old products they had previously been asked to bring to the class, such as old remote controls and digital cameras (Fig. 3). Second, students discussed how the products, once taken apart, could be redesigned to increase their circularity based on the 9R framework (Fig. 2). The circular product ideas developed ranged from an app that would function as a remote control to a product-as-a-service digital camera company. We also specifically discussed how start-ups with a circular business model may contribute to CE (Kirchherr et al., 2014). It was observed that students with a more technical disciplinary background helped those with a background in the social sciences during the teardown labs. This helped to enhance the learning experience of social sciences students and may thus be considered a case in point for recruiting students with multiple backgrounds to CE courses. Overall, students liked the teardown lab (Fig. 5), but they asked for more lecturing, which would have been on engineering for sustainability (Hein et al., 2015), prior to the exercises in order to obtain additional theoretical grounding.

This feedback was incorporated in the third module, which introduced students to the idea of eco-industrial parks (EIPs). EIPs can be defined as a set of businesses that share resources in order to increase profitability and reduce environmental impacts (Jackson et al., 2014; Sakr et al., 2011). First, a lecture on the topic was given by a recognized scholarly authority on the topic with the scholar explaining the concept of EIPs, its relation to the CE (*e.g.*, the focus of both concepts on reusing and recycling), as well as drivers and barriers that firms are facing within EIPs, with one notable barrier being the coordination costs that firms face in an EIP (Chertow, 2000).

To reach ILO 3 (Table 1), these drivers and barriers were further explored via an eco-industrial park (EIP) simulation performed with students in the second half of this module. Students were divided into 10 groups with distinct organization profiles for this exercise, and then they had to form two EIPs, which were both supposed to maximize employment, the annual revenue, and the number of material exchanges—a reflection of the triple bottom line. Overall, the students liked the module, whereas they said that explanation of the EIP simulation could have been more straightforward.

The aim of the fourth module was to introduce students to the likely macroeconomic impacts of the CE and to outline policy instruments that could be adopted to further amplify CE's macro benefits (*i.e.* ILO 4, Table 1). The module started with a lecture on the macroeconomic impacts of CE. The difficulties of undertaking such impact calculations and the subsequent uncertainties associated with them were discussed in-depth as part of this lecture. For instance, the rebound effect concept was introduced as part of this module (DoF, 2017) (with the rebound effect also appearing as a core challenge to CE in the CE teaching by Kopnina (2017)). In the second part of the module, students were asked to develop policy instruments to further enhance CE's alleged positive impacts. These were rated based on the weighted scoring method, which was criticized by students as being too complex for the limited amount of time (15 min) given for the exercise.

The fifth module and the sixth module consisted of excursions. First, an excursion was made to Interface, a global carpet company founded in the Netherlands that produces new carpets by recycling old ones and runs only on renewable energy at Scherpenzeel, its largest manufacturing site in the Netherlands (Interface, 2017). The first excursion highlighted to students the potential trade-offs between social inclusiveness and environmental resilience as two aims of the CE (ILO 2, Table 1); Interface staff shared that a newly purchased carpet cutting machine (developed by NASA) would significantly reduce carpet waste produced by Interface, but it would also induce the layoffs of staff members who currently perform this cutting. Second, an excursion was made to Blue City Rotterdam, which sees itself as a co-working space for circular start-ups that enables them to exchange ideas with the intention of accelerating the transition towards the CE (Blue City Rotterdam, 2017). The second excursion, in particular, contributed to the achievement of ILO 3 (Table 1) by demonstrating to students that the CE's aim of economic prosperity can also stop (or at least slow down) the CE when the staff from Blue City Rotterdam revealed that the

Table 2
Constructive alignment between intended learning outcomes (ILOs), supporting teaching and learning activities/materials, and assessment tasks.

Module	Author(s)	Paper title	Reason for Selection	'Gains' from the Reading	Supporting Learning Activities	Assessment Method	Moments of Struggle
1- Introduction (ILO 1)	Chertow (2000)	Industrial Symbiosis: Literature and Taxonomy	Situating 'Circular Economy' in the broader sustainability context	How 'Circular Economy' and 'Industrial Symbiosis' are interrelated	Drill game (group exercise that encourages students to reflect on the main promise of the circular economy for businesses to cash out on sustainability) Buzzword bingo (group exercise that encourages students to relate circular economy to industrial symbiosis, sustainability, green economy and biomimicry)	Presentation of group work results ('Supporting learning activities')	Students found not only 'Circular economy' an ill-defined term, but also the other terms they were supposed to relate the CE to
	Geissdoerfer et al. (2017)	The Circular Economy: A New Sustainability Paradigm?		How 'Circular Economy' and Sustainability' are interrelated			
	UNEP (2011)	Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication		How 'Circular Economy' and 'Green Economy' are interrelated			
	Vanaga and Blumberga (2015)	First Steps to Develop Biomimicry Ideas		How 'Circular Economy' and 'Biomimicry' are interrelated			
2- Applied Theory: CE at the Micro-Level (ILO 2)	Bocken et al. (2016)	Product Design and Business Model Strategies for a Circular Economy	One of the most cited articles on circular economy at the micro-level	Fostering understanding of the micro-level (product level) of the circular economy	Tear-down-labs (asking students to tear down items, *e.g.* cell phones, to start thinking more deeply about repairability, disassembly, *etc.*)	Presentation on the most radical (circular) product design and underlying business model	N/A
	Tukker (2015)	Product Services for a Resource-Efficient and Circular Economy? A Review	One of the most cited articles on circular economy at the micro-level	Fostering the understanding of product-service systems as a core dimension of the circular economy			
3- Applied Theory: CE at the Meso-Level (3) (ILO 3)	Chertow and Lombardi (2005)	Quantifying Economic and Environmental Benefits of Co-Located Firms	One of the most cited articles on circular economy at the meso-level with M. Chertow also being one of the most celebrated authors on eco-industrial parks	Gaining a quantified understanding of circular economy benefits	Eco-industrial park simulation game	N/A	Identifying a sufficient number of connections in the eco-industrial park
	Heeres et al. (2004)	Eco-Industrial Park Initiatives in the USA and the Netherlands: First Lessons	One of the most cited articles on circular economy at the micro-level with an explicit connection to the Netherlands	Improving one's understanding of policy drivers as core drivers for a circular economy			
4- Applied Theory: CE at the Macro-Level (ILO 4)	Bastein et al. (2013)	Opportunities for a Circular Economy in the Netherlands	Relevance for circular economy in the Netherlands	Gaining a quantified understanding of circular economy benefits	Policy instruments (students developing policy instruments to accelerate the transition towards a circular economy)	Presentation on circular policy instruments	Scoring method too complicated for the limited amount of time given for the exercise
	McDowall et al. (2017)	Circular Economy Policies in China and Europe	Insightful comparative analysis for circular economy in Europe and China	Improving one's understanding of policy drivers as core drivers for a circular economy			
5- Practice: CE at the Micro-Level (ILO 2)	De Groene Zaak and Ethica (2015)	Boosting Circular Design for a Circular Economy	One of the most cited articles on circular economy at the micro-level	Fostering understanding of the micro-level (product level) of the circular economy	Trip to a manufacturing company producing circular carpets	N/A	N/A
	Moreno et al. (2016)	A Conceptual Framework for Circular Design	One of the most cited articles on circular economy at the micro-level	Fostering understanding of the micro-level (product level) of the circular economy			
6- Practice: CE at the Meso-Level (ILO 3)	Valenzuela-Venegas et al. (2016)	Sustainability Indicators for the Assessment of Eco-Industrial Parks: Classification and Criteria for Selection	One of the most cited articles on circular economy at the meso-level	Gaining a quantified understanding of circular economy benefits	Trip to an eco-industrial park	N/A	N/A
	Zhu et al. (2015)	Barriers to Promoting Eco-Industrial Park Development in China	One of the most cited articles on circular economy at the meso-level	Gaining a nuanced understanding of the barriers to the development of eco-industrial parks			

(*continued on next page*)

Table 2 (*continued*)

Module	Author(s)	Paper title	Reason for Selection	'Gains' from the Reading	Supporting Learning Activities	Assessment Method	Moments of Struggle
7- Practice: CE at the Macro-Level (ILO 4)	Ellen MacArthur Foundation (2015)	Growth Within: A Circular Economy Vision for a Competitive Europe	Groundbreaking report on the impacts of a circular economy	Comprehensive overview of circular economy benefits in Europe	Circular party (students developing and assessing the wider environmental, social and economic impact of circular business models)	Level of nuance/depth of the circular business model and impact analysis	N/A
	Stegeman (2015)	The Potential of the Circular Economy	Report on the impacts of the circular economy in the Netherlands	Comprehensive overview of circular economy benefits in the Netherlands			
8- Conclusion (ILO 5)	Boulding (1966)	The Economics of the Coming Spaceship Earth	The first text ever written on a circular economy	Gain understanding of the historical roots of the circular economy	Circular futures (students envisioning different circular futures)	N/A	N/A
	(Skene, 2017)	Circles, Spirals, Pyramids and Cubes: Why the Circular Economy Cannot Work	A critical piece on the circular economy	Gain critical understanding of the circular economy			

organization charged circular start-ups €275 per square meter per month, a price that many relevant circular start-ups cannot afford.

For the seventh module, a CE party was organized with different student groups asked to bring circular foods or drinks to this party and to describe and quantify the economic, social, and environmental impact of the circular business model behind these foods or drinks (ILO 4, Table 1). Specifically, students created business models on R1, as outlined in Fig. 2, which were product-as-a-service business models, which then also prompted a discussion regarding the similarities and differences between the sharing economy and the CE – a continuation of a discussion already started in module 1 when discussing Potting et al. (2017). The CE butterfly diagram developed by the Ellen MacArthur Foundation (2015) with CE's biological and technical cycles was also part of the preparatory readings for the module and discussed in class with the students. Overall, the students commented that they found the change from the "applied theory" lectures to the (even more applied) excursions and the party refreshing.

The course closed with the eighth module, which aimed to integrate previous CE lessons from the course and outline their implications. First, this module provided a summary of all contents covered in the previous modules. Second, this module was used for a futures exercise, inspired by Kopnina (2014). For this exercise, students were presented three different futures scenarios regarding the circular economy (Fig. 4). As a second step, students were divided into six groups, with each group then asked to develop five newspaper headlines for the year 2030 for the specific scenario the group was assigned to. The purpose of this exercise was to encourage students to envision and think about different – more or less desirable – circular futures (ILO 5, Table 1). Newspaper headlines typically outline only the most notable events. Asking students to depict futures via newspaper headlines thus helped ensure that the students would present them as pointedly (and thus possibly as tellingly) as possible. Students expressed appreciation regarding this final module that enabled them to bring together all the CE knowledge gained during the course for the development of the headline.

4.3. Course evaluation

Overall, the course was evaluated by the students with an 8.0 (on a scale from 1 to 10, with 10 being the most positive grade that can be awarded in the Netherlands), which is an excellent rating for courses at Utrecht University. The average course rating in the relevant bachelor's programs at Utrecht University is a 6.7, with only three other courses in these programs achieving an 8.0 in the previous year and no course in the previous year exceeding a rating of 8.0, according to data shared by the university administration. It can be concluded that the outlined education for the CE approach was well received by the students.

The course rating collected at the end of each module is depicted in Fig. 5. None of the ratings of specific modules reached a score higher than 7.4, despite the course's overall rating of 8.0 (with n = 36 for the final evaluation). One of the teaching assistants for the course suggested that this "has to do with the fact that students are more critical during a seminar since they carefully [remember at the end of each seminar] what they dislike. However, when looking back at the entire period, those small troubles do not matter that much."

The main room for improvement within the course, according to the final evaluation, was the level of difficulty with some students finding it too easy and some too difficult (Fig. 6). This may have been caused by students enrolling for the course in different years of their Bachelor program; indeed, those who found it too easy are mostly from the later years of the respective Bachelor programs, while those who found it too difficult are students who just started university. An idea could be to only recruit students at the same level of their university careers for future iterations of such a course.

The second area for improvement relates to time management. A variety of modules were too hurried since the exercises usually took

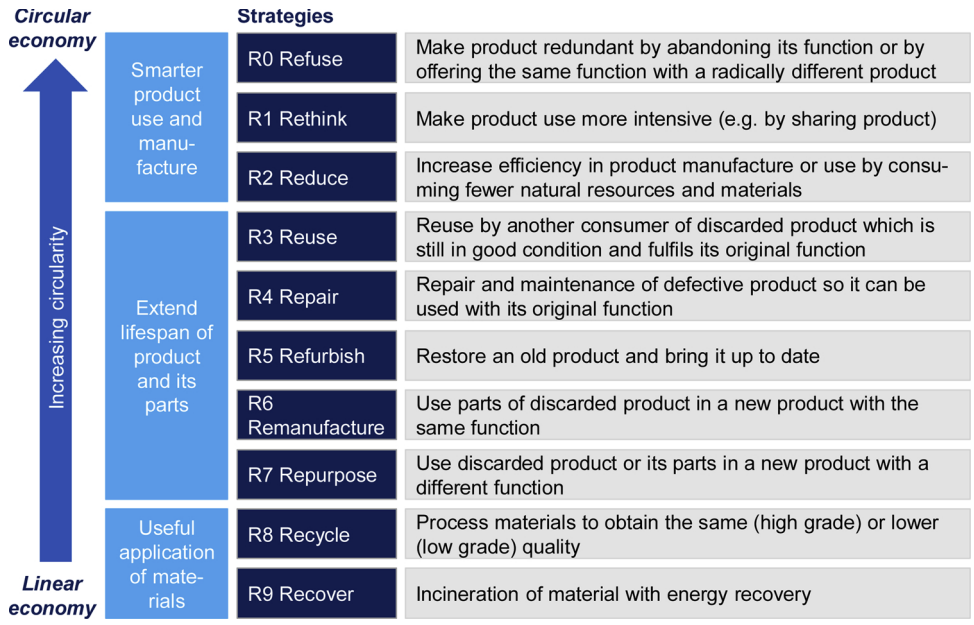

Fig. 2. The 9R Framework on the Circular Economy (CE).
Note: Written permission to use these photos was obtained from the students depicted.

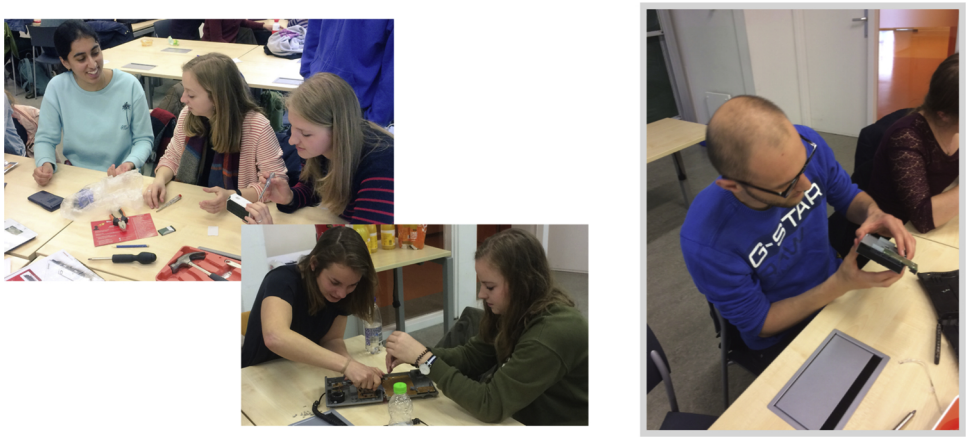

Fig. 3. Impressions from the teardown lab (module 2).

more time than anticipated. It is acknowledged that the insufficient time allocation to various exercises likely (at least partially) undermined their results. Students would possibly have created more nuanced solutions and gained deeper insights if more time had been allocated to the various exercises. The relative lack of experience of the first author of this paper as a lecturer may be the main reason for the insufficient time allocation to various exercises. Lecturers aiming to integrate the exercises developed for this course into their teaching are advised to allocate much more time to them (at least 30 min for group work per exercise) than what was allocated to them for this course.

Some students who raised "time management" as an area for improvement particularly criticized the two excursions, arguing that these took up too much time in comparison to the insights gained from them. Indeed, the number of excursions conducted as part of this course may have been excessive. Limiting the number of excursions to one may create space for exercises that are not rushed but carried out with the time needed for students to generate more nuanced solutions and deeper insights.

The main strength of the course, according to the final student evaluation, was its first core principle: interactivity (Fig. 6). This (in combination with the excellent overall course evaluation, as outlined earlier) suggests that the chosen interactive teaching approach contributed to the learning experience of students. Hence, the various exercises outlined in this paper and detailed in the supplementary materials may be particularly leveraged by those interested in teaching the CE.

		SCENARIOS		
	DIMENSION	1	2	3
A	**Core principle**	Recycling	Reusing, recycling	Reducing, reusing, recycling
B	**Dominant business model**	Buy-and-own	Buy-and-own/ Product-as-a-service	Product-as-a-service
C	**Organization of loops**	Decentralized (by businesses)	Centralized (by government)	Mixed (by businesses and government)

Fig. 4. Possible circular economy futures.
Note: n = 36.

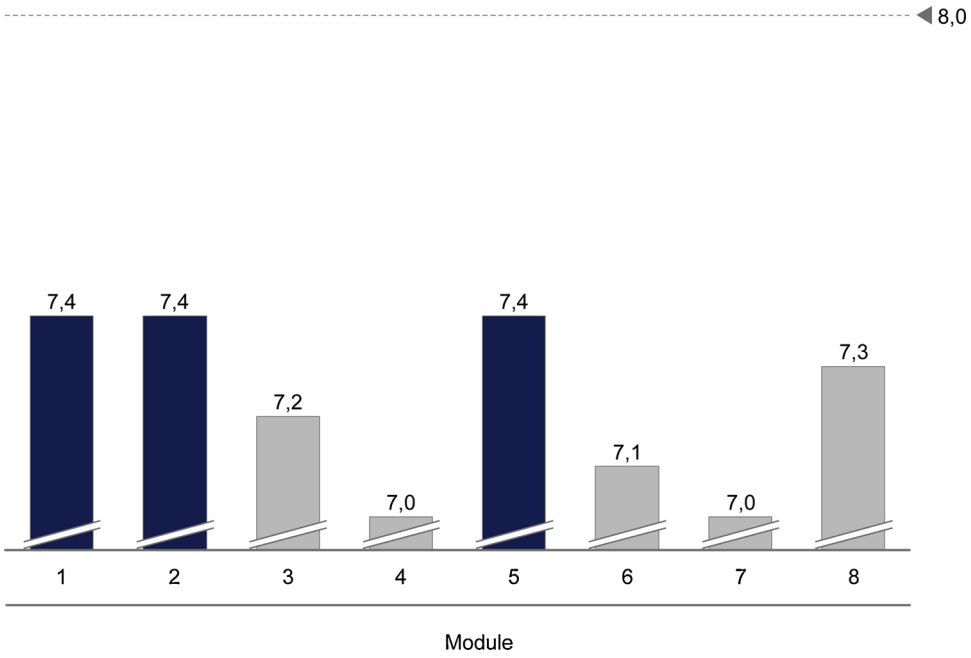

Fig. 5. Course ratings for each module of the course 'The Circular Economy: An Introduction'.
Note: n = 36; the figure only lists strength mentioned > three times.

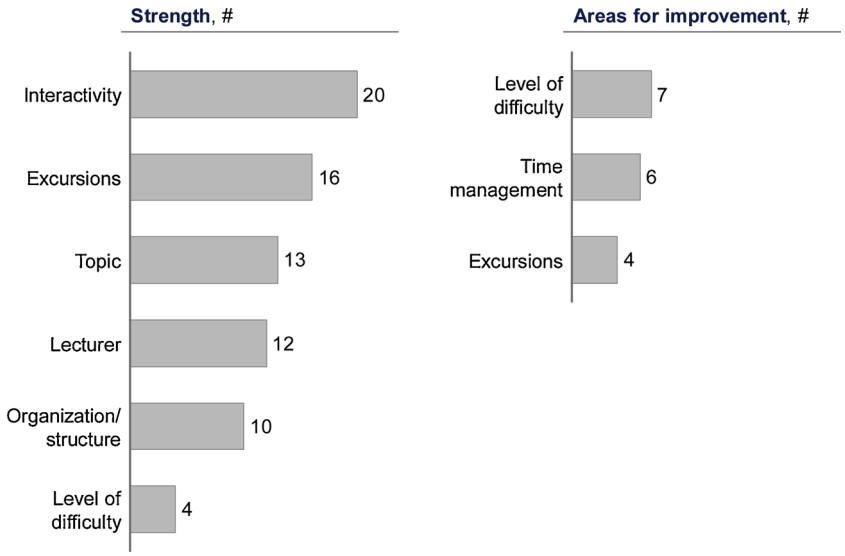

Fig. 6. Strengths and areas for improvement regarding the course 'The Circular Economy: An Introduction'.

The second main strength of the course, excursions (which somewhat relativizes the previously mentioned criticism regarding "excursions"), may be considered as a variation of the interactivity principle, with excursions also being the opposite of the traditional teacher-up-front style. The topic "circular economy" appears as the course's third main strength. It can be argued that this result further indicates the potential of the CE concept as a pathway to sustainability, as outlined in Section 1.

5. Discussion

If the course were to be retaught[12], more time would be allocated to various exercises. Some more lecturing elements would possibly be moved toward the preparation phase for each module to enable this, and only one excursion would be conducted to provide further space for this. Considering that interactivity proved to be the most popular element of the course, this element would be further expanded. For instance, the drill game exercise could be expanded toward an actual case study, and students could also be asked to elaborate on a business strategy for the Chinese manufacturer in both scenarios. This revised case study would then not only focus on recycling (which is not a particularly high value retention option, as evident from Fig. 2) as a business strategy towards circularity, but would also consider higher Rs such as 'Refuse' or 'Rethink'. Furthermore, the macro-level lecture, one of the least popular lectures (Fig. 5), would be redesigned.

[12] The first author of the paper, who delivered this CE introductory course, (mostly) returned to the private sector. Since this course was only offered as an elective, it is unclear if it will be picked up by another lecturer/retaught anytime soon at Utrecht University's Faculty of Geosciences.

The scholarly literature on teaching the CE provides further ideas for the refinement for this course. First, it could also be considered (as an alternative excursion) to visit a small and medium-sized enterprise that has not yet embraced CE to gauge an SME's perspective regarding CE; Kopnina (2017) finds that such visits enhance students' understanding regarding CE barriers. Second, another iteration of the course may situate CE not only in the sustainable development discourse, but may also discuss competing paradigms; Huckle (2012, p. 848) would have probably criticized this course for "[overlooking] the role of neoliberalism" in impeding the transition towards a CE (this criticism would have likely also been raised by Kopnina (2015b)). A future CE course should also include examples of CE green-washing, *e.g.* PlantBottle by the Coca-Cola enterprise, as discussed by Kopnina (2017).

It is estimated that the development and teaching of this course took around 250 h. Since the first author of this paper was relatively inexperienced as a lecturer, as outlined earlier, he likely needed more time to prepare the course activities/materials and teach than a more experienced lecturer would have. While the development of high-quality education for the CE is likely to benefit from extensive teaching and preparation time, it should however be noted that several authors, including Barth (2013); Lozano (2010) and Wu and Shen (2016), have pointed out that the institutional support for ESD (which includes the allocation of resources to course development) is frequently limited.

6. Conclusion

The circular economy (CE) is gaining traction as a novel pathway to sustainable development among both practitioners and scholars. Much of the discussion of the CE has highlighted the significant role the private sector can play in the transition towards CE. However, lecturers in higher education can also play a significant role. Yet, only a limited amount of work has outlined or critically reflected upon lecturers' roles and the resulting education for the CE (ECE).

The contribution of this paper is to outline a specific approach to introduce students to the CE concept without focusing on a specific CE aspect, such as design. The outlined approach is grounded in five proposed core education for the CE principles: interactivity, non-dogmatism, and reciprocity as well as constructive alignment and problem-based learning, and it entails seven novel circular economy exercises: a drill game, buzzword bingo, a teardown lab, an eco-industrial park simulation, policy instruments, circular party and circular futures.

Since the outlined CE teaching approach proved to be popular with students, it may be used by lecturers who are also keen to incorporate the CE concept into their teaching. Students liked the CE topic as such, and they also enjoyed the interactive exercises and excursions. However, students expressed less satisfaction with the level of difficultly and the time management of the course. Those keen to learn from the areas for improvement are advised to recruit at the same level in their university careers, while also allocating much more time to the interactive exercises outlined.

It is acknowledged that the insights outlined in this paper face several limitations. The first limitation relates to the methodological approach chosen for this study, as this paper is based on a single education for the CE approach. This approach was aimed at undergraduate students. Master's students may already require a more advanced introductory CE course. Furthermore, this paper does not address CE teaching beyond the introductory level. Hence, future work on education for the CE may outline what successful advanced CE teaching may look like. Future writing on education for the CE may also reflect more specifically on how CE's conceptual predecessors may contribute to education for the CE. While the design of this CE introductory course drew heavily on insights from the ESD literature, another predecessor with potential regarding education for the CE may be the field of industrial ecology, as outlined earlier. It is further noted that the assessment of the course effectiveness mainly relies on the feedback provided by the students, which needs to be considered with caution. For instance, this can result in a questionable lowering of standards, with students usually preferring a course with a low/medium level of difficulty as opposed to one with a high level of difficulty; however, the mastering of complex topics and skills requires the latter type of course. Hence, future research reflecting on education for the CE may also include collecting the feedback of experienced colleagues regarding a specific course.

It is yet to be seen if education for the CE (ECE) will emerge as a separate field of study - just as ESD has. The authors of this paper would welcome this. Those scholars keen to integrate the CE into their respective curricula are believed to benefit from sharing teaching materials and reflections on the CE (such as this study) in any way. It is hoped that this paper will encourage scholars to share their best practices regarding CE teaching and to contribute additional reflections regarding education for the CE. It is believed that a scholarly dialogue on education for the CE will improve CE teaching quality which, in turn, can only help enhance higher education's contribution in a transition towards a CE. The private sector can and must certainly play a significant role in this transition, but the authors of this paper firmly believe that those teaching in higher education can play a similarly significant role, given their direct involvement with those who will shape tomorrow's world.

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