

The progression of Awareness of Circular Economic Principles within Civil Engineering

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Abstract

Circular Civil Engineering is applying the circular economic principles to civil engineering. The circular economy is a model of production and consumption, which results in absolute minimal waste. Some of the main challenges to its implementation include lack of policies, design for end of life, unclear circular economy framework, and lack of awareness. This research focuses on the awareness and knowledge on the subject within students and postgraduates in industry. The data for this project was collected through an online survey and resulted in most of respondents having a relation with the University of the West of England. The survey focused on how confident students and postgraduates are on their knowledge, as well as researching previous implementation of the circular economy in universities and the working industry. This research found that progression of awareness has been made over the years, but not on a large enough scale.

1. INTRODUCTION

Circular Civil Engineering (CCE) is applying circular economic principles to civil engineering. The Circular Economy is a model of production and consumption, which involves recycling, refurbishment and reuse of any existing materials and resources, resulting in minimal waste. In contrast to reducing carbon emissions, the circular economy aims to be a zero-waste system.

Civil Engineers have a key role to play in the transition from a linear model to a circular one. The construction industry is one of the largest consumers of energy and raw materials. It is taking its toll on the environment; In the UK, construction, demolition, and excavation account for 60% of material use and waste generation ('Circular Economy', 2021). Shifting from a linear to a circular economy would bring significant ecological improvements.

Changing mindset however is one of the greater challenges. Often industry standards are based on policy, law, and codes within a jurisdiction. These policies, laws and codes are created, supported, and carried out by engineers (Carroll, 2021). Engineering students are driven by change and commitment to a better world; They are 'future builders' and as such, they play a key role in the transition from a linear to a circular model.

The issue that this document is going to address is that there is very limited information or studies on whether any progression has been made with a comparison between the postgraduates and current engineering students of their awareness on CCE.

2. LITERATURE REVIEW

Adams et al (2017) found that limited awareness, interest, and knowledge are identified as significant challenges. The other challenges mentioned were legislation, lack of design for end of life, recovery of materials, the economic factor, and fixed linear mentality. Some of the challenges identified (Adams et al, 2017) were the lack of incentive to design for end-of-life issues, followed by the lack of market mechanisms to aid greater recovery and an unclear financial case. The paper also concludes that at an industrywide level there was a lack of awareness of CCE.

Limited awareness, interest and knowledge are identified as significant challenges. In the survey done by the ICE (Institution of Civil Engineers), Survey respondents with greater construction experience believe that a lack of interest was a highly significant challenge (Adams et al, 2017).

To improve the awareness, Andrews (2009) suggests that “[CCE] must be embedded in design curriculum from the first year so that students recognised these principles should be core to all design activities.”

Examples of the raising awareness of the Circular Economy are given in Table 1 below and two cases will be further discussed later in this document.

Table 1 - Four examples of raising awareness of CCE

Examples	Information
The Interdisciplinary Sustainable Development Module, Manchester	In the University of Manchester, an elective module was created for Year 3 undergraduate students and has been offered for several years (since 2012). The starting point of this work was an action research project sponsored by the Royal Academy of Engineering that took place in 2008 (Tomkinson et al, 2016).
Symposium 5: The Royal Academy of Engineering (RAEng)	Engineering ‘Frontiers of Engineering for Development’ symposium on CCE took place in early May 2018 with support from the Circular Economy Club. The Frontiers of Engineering for Development hosted various themed symposiums a year to bring together the best early to mid-career researchers and practitioners from industry, academia, and government.
British Standards Framework for Implementing the Principles of the Circular Economy in Organizations – Guide BS8001-2017	There is currently a lack of standardisation in place for the circular economy concept however the British Standards Institution published its first voluntary practical framework and guidance in 2017 to help organisations adopt circular economic approaches. BS 8001-2017 aims to give guidance to companies worldwide and to provide them with an understanding of what the circular economy is and how it is relevant to current issues, and how to implement these issues.
CL994 Circular Economy and Transformation towards Sustainability Module, Glasgow	The CL994 Masters Module provided by the University of Strathclyde Engineering, Glasgow is geared towards civil and environmental engineering students as well as other relevant studies. This module introduces the Circular Economy as a framework for the development and management of a sustainable 'waste-as-resource' economic system.

The Interdisciplinary Sustainable Development (ISD) module in Manchester This secondary data was extracted from the paper ‘Educating civil engineers for Circular Economy’, and additional data and information was extracted through personal emails to the director of the Entrepreneurship Sector (in charge of the optional ISD module), and this will be further discussed in the paper.

Engineering ‘Frontiers of Engineering for Development’ and the data extracted of the feedback from participants at this symposium was extracted by personal emails to the Senior Manager

of Sustainable development at the Royal Academy of Engineering. This data consists of questionnaire feedback taken over SurveyMonkey. This data is informative as it shows how people respond to this subject in engineering on a working level and shows if there was any positive feedback over bringing light to this topic.

3. RESEARCH DESIGN AND METHODOLOGY

Figure 1 shows the course of how the research and analysis has been produced. The survey was used to gather primary information on if there had been a difference of awareness within postgraduates and current students. In order to find secondary data, people involved in the RAEng and the Manchester Module were contacted to see if there was any feedback on these projects.

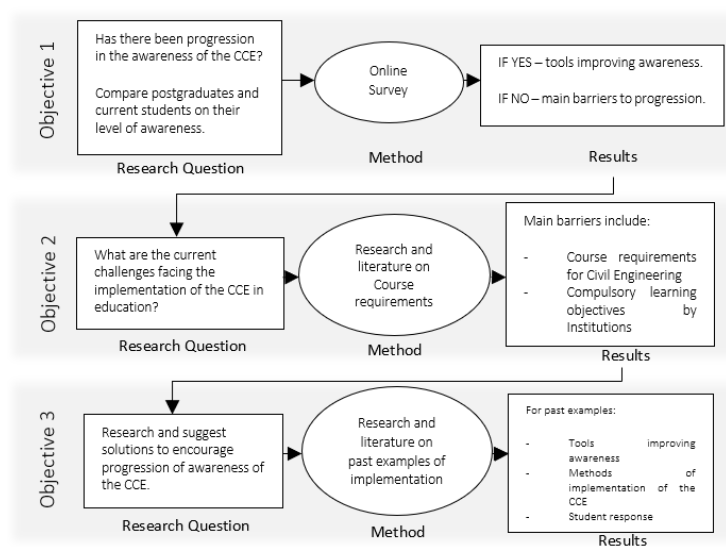


Figure 1 - Flowchart to demonstrate the structure of the research.

Objective 1: To compare students and past students on their level of awareness of CCE

An online survey was used to establish students and postgraduates' level of awareness of CCE, and their view on the importance of the challenges and enablers for greater adoption. The purpose was to gain information about whether CCE is taught, and the comparisons of the awareness of current students to postgraduates who are taking or have taken civil engineering.

The survey was available for completion over a one-month period on the Qualtrics XM UK platform. Table 2 shows who took part in the survey and how they were contacted.

Table 2 - Types of people contacted, how they were contacted and why this method was appropriate.

Types of people	How they were contacted	Why this method
Civil Engineers	Through email, and promotion on professional social media platforms such as LinkedIn.	One-to-one emails are a good way to get answers directly, and LinkedIn is a great platform to gain data from professionals.

<i>Civil Engineering Students (and other construction related courses)</i>	Through Social media platforms targeting civil engineering societies (such as FB, Instagram, LinkedIn, and page societies), posters displayed, and one-to-one emails.	This is a great way to gather responses quickly and easily. The societies are a good way to gather information from a selected group of people.
<i>Lecturers</i>	Through one-to-one emails, and in person promotions.	Emails are a good way to get sources directly.
<i>Other professionals (e.g., consultants)</i>	Through emails, and promotions on LinkedIn.	Emails are a good way to collect answers directly, and LinkedIn is a great platform to promote.

The questionnaire was a total of 13 questions. The general question structure will be enclosed in Table 3.

Table 3 - Survey questions, with relevant information

Question	Who it targeted	How it is answered	Why this question was chosen
Q1. Are you currently studying in university, or are a graduate?	Students and graduates	YES/NO box	It made a clear comparison for those who are currently in the civil engineering curriculum, and those who have left and are working.
Q2. If a student, Which year are you in?	Students	Checkboxes of 1 st , 2 nd , 3 rd , Foundation and Master Year boxes.	This is a categorial question to see the range of years.
Q3. If not in university, what is your job title?	Graduates	Text box	This is a categorial question to collect the job roles within the construction industry.
Q4. Which course are you studying?	Students	List of relevant courses with 'Other' box.	This is a categorial question to see the range of courses.
Q5. Which university did you, or are you attending?	Students and graduates	Text box	This is a categorial question to see the representations of universities.
Q6. Have you heard of the Circular Economy?	Students and graduates	YES/NO box	This question is to see whether participants are aware of the topic.
Q7. If you had, where did you hear about the Circular Economy?	Students and graduates	Checkboxes of 'University', 'Work', 'Individual research' and 'Other'.	This is gathering information on if they had heard of it, how they came about to do so.
Q8. How confident do you feel about your knowledge on the Circular Economic Principles within engineering?	Students and graduates	A five-point scale ranging from 'Very poor' to 'Excellent'.	This question gauges the respondents' level of awareness and confidence on the topic. 5 Point Likert Scale is frequently used because respondents can easily answer questions in this format. They are simple and easy to analyse.
Q9. Which principles have you heard of when it comes to applying Circular Economy in engineering?	Students and graduates	Checkboxes principles of: 'Design for End of life', 'Material Passports and selection', 'Raising awareness', 'Relevant Policies', 'Clear Framework' with the choice of 'Other'.	This checkbox question provides insight on how aware participants are of the kind of challenges CCE current application is facing.
Q.10 Which, from the above, do you think is of the least importance.	Students and graduates	Checkboxes with the same principles given above.	This question provides information on which principle holds the least importance to each pool of participants.
Q11. Which do you think is of the highest importance?	Students and graduates	Checkboxes with the same principles given above.	This question provides information on which principle holds the most importance to each pool of participants.
Q12. Rank the following challenges facing circular civil engineering.	Students and graduates	Ranking system with different challenges such as 'Lack of awareness', 'unclear financial case', 'lack of collaboration',	These questions collected data on what challenges hold the most importance to both students and postgraduates. There are many other challenges aside from raising awareness to CCE, and this question aimed to

		'lack of end-of-life incentives', 'lack of relevant policies' and 'linear methods'.	gauge which challenges participants think are important, while informing the participants of other challenges related to raising awareness of CCE.
Q13. Suggest any ways we could raise more awareness within different sectors of the industry.	Students and graduates	Text Box for qualitative information.	Open ended questions provide a better understanding about the respondents' feelings and attitudes and allows respondents to include more contextual feedback through qualitative information.

Some limitations are that it excludes 4th year students (Glasgow), and it doesn't give an option box for people doing other types of educational journeys such as an apprenticeship however if this research was to be amended or continued, then it would be a suggestion to gather more broad results.

Objective 2: To research challenges that have obstructed progression of knowledge of CCE

Objective 2 will be addressed by reviewing the degree course guidelines from the Institution of Civil Engineers (ICE). Since the majority of the data was collected from students, graduates, and lecturers from UWE (University of the West of England), the course specifications of the 'Civil and Environmental Engineering' or 'Civil Engineering' programmes from UWE will also be reviewed. Not including course specifications from other institutions is a limitation of this research that is considered in the discussion of the results below.

Both the learning outcomes from the course specifications of 'Civil Engineering' according to UWE, and the ICE course guidelines for accreditation were found through both institutions and their websites. This is of relevance in terms of whether any assessments demonstrate awareness of CCE.

Objective 3: To research and suggest solutions to encourage progression of awareness

Objectives 3 will be addressed through a review of the literature. In the process of researching and then making recommendations, previous examples of how CCE has been implemented in current higher education were found. Key words or phrases for finding this information are: 'Circular Economy', 'Sustainable Development', 'Education', and 'Implementation'. There were around six documents obtained on the Circular Economy and its implementation, however only two examples were chosen because of its relevance to the implementation of CCE, one in higher education and the other in industry. One was the Interdisciplinary Sustainable Development Module, Manchester (Tomkinson et al, 2016) and the other was the Symposium 5: The Royal Academy of Engineering ('Frontiers of Engineering for Development 2018 - SurveyMonkey', 2018)

4. RESULTS

The data consisted of 71 valid responses, with 35% being postgraduates and 65% being current students. The sampling frame comprised of engineers, managers, technicians, consultants, and lecturers. Of the current students (in civil engineering and other related courses) the data sample consisted of 19.5% masters, 52.2% third years, 10.9% second, and the remaining 17.4% in their first and foundation years.

The data sample consisted of a range of participants from different universities over the UK (as shown in Figure 2). However, most of the participants (XX%) were studying or had studied at UWE. This limitation will be discussed further in the discussion section.

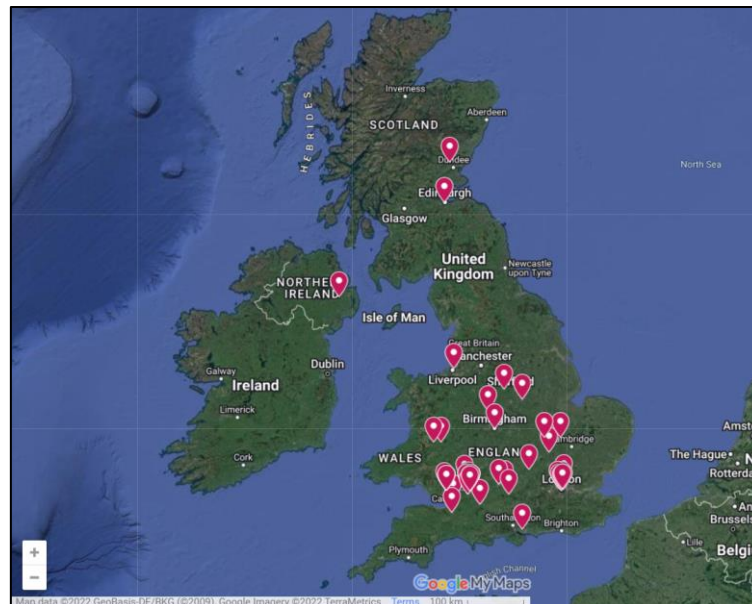


Figure 2 - Geographical Institution Spread

Out of 71 participants, 28% answered that they had not heard of the Circular Economy, while 72% said that they had. This data and the difference between the parties is represented in Figure 3. If the participants had answered yes, Figure 4 shows this data of how they knew about CCE.

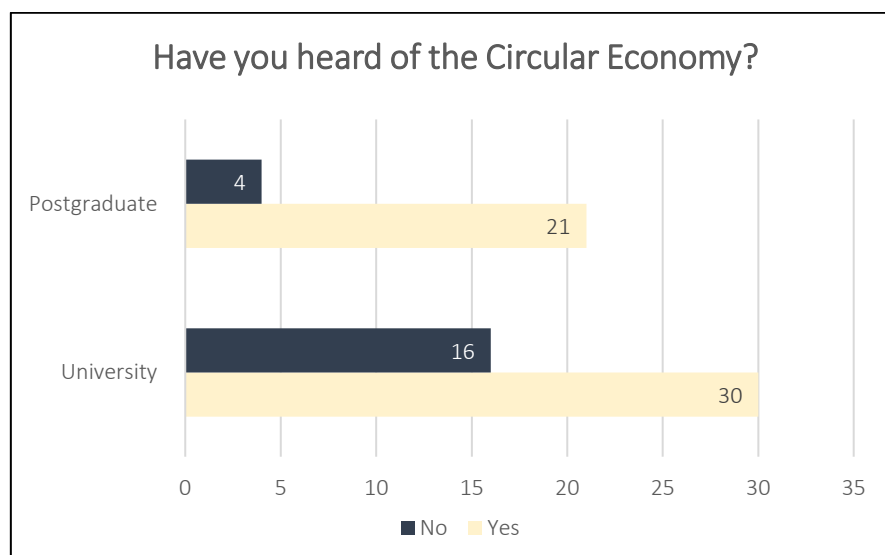


Figure 3 Participants' awareness of the Circular Economy.

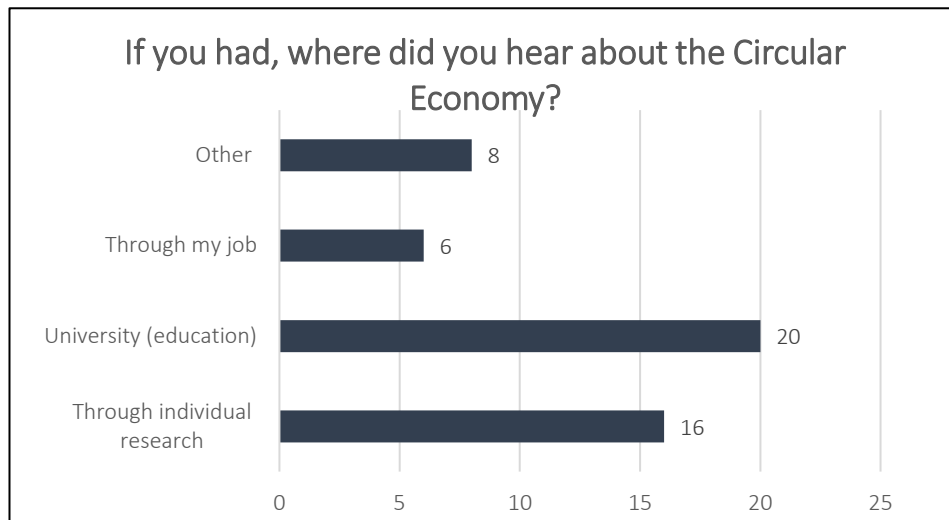


Figure 4 - How participants knew about the Circular Economy

Participants were then asked to rate how confident they felt about their knowledge on CCE. This data is represented in a graph in Figure 5.

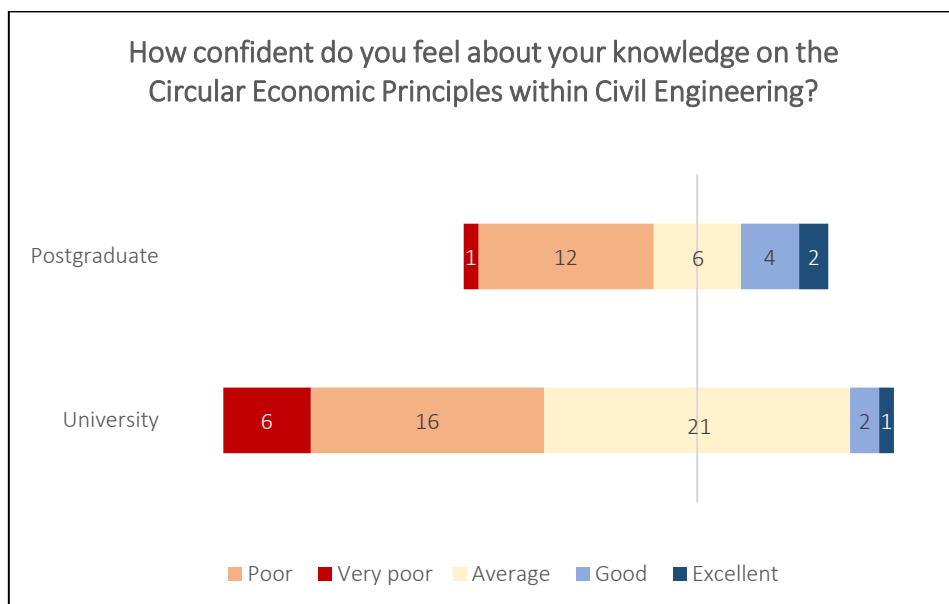


Figure 5 - Participants rating their confidence on CCE

Participants were asked to checkbox how many policies of CCE that they were aware of. The policies given in the questionnaire were 'Design for End of Life', 'Material Passports and selection', 'Raising Awareness for CCE in Industry & Education', 'Relevant Policies (supporting CCE)', and 'Clear CCE Framework'. Another option was given called 'Other' with a box for qualitative data for any missed. The number of policies they knew were counted and this is represented in Figure 6.

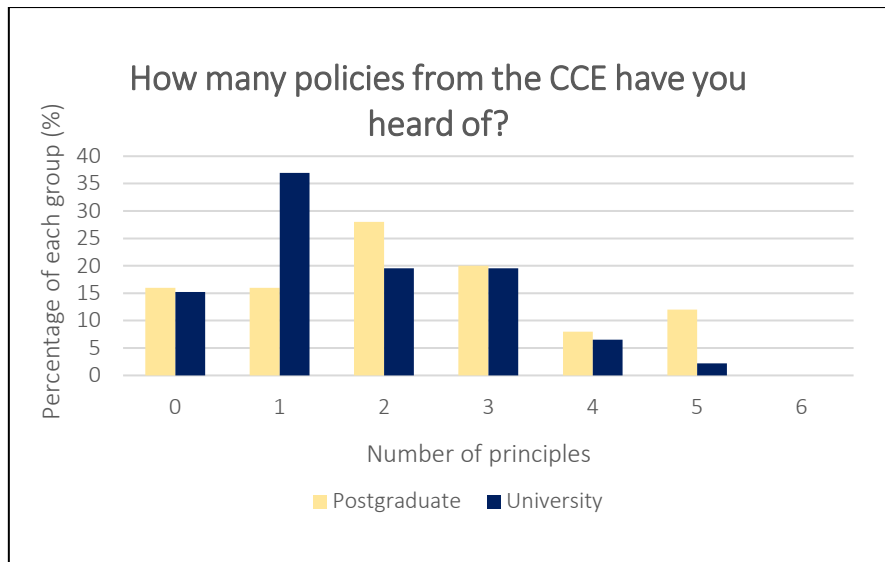


Figure 6 - Percentage of people knowing policies of CCE.

The next question was asking partakers to rate which of these principles would be of the highest importance. This data is represented in Figure 7. From the pool of postgraduates, the highest percentage (24%) chose Raising awareness, however with the students the highest percentage (34.78%) chose Relevant policies to be the most important.

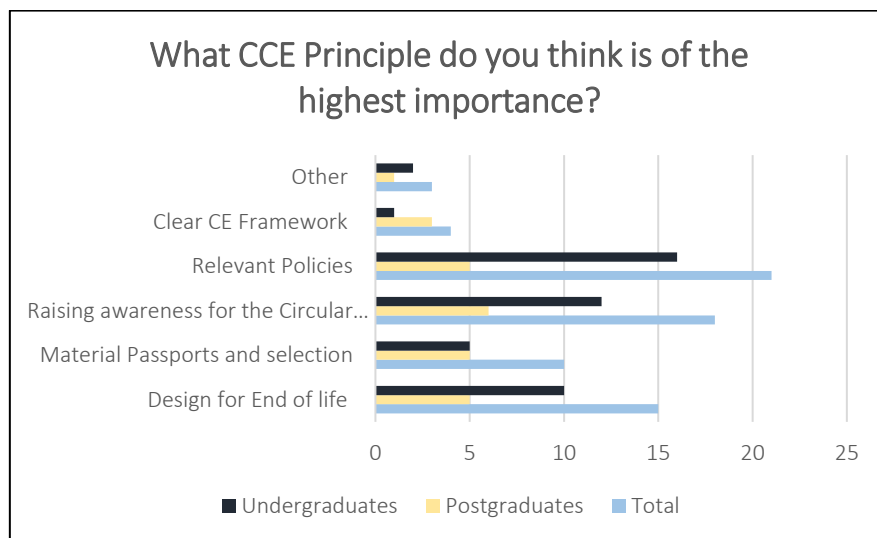


Figure 7 - Which CCE principles are the most important to participants.

There are several challenges facing the implementation and progression of CCE, and participants were asked to rank the challenges. The most common answer given by the postgraduates to be the most important was 'Unclear Financial case for client and stakeholders'. For students, the most common answer ranked 1st was 'Lack of awareness and knowledge on the Circular Economy'.

The last and final question was an open question asking participants to suggest ways of raising awareness of CCE, whether in industry or higher education. The Key words from all recommendations were extracted and then put into a Word cloud, using MonkeyLearn, as shown in Figure 8.



Figure 8 - Word cloud of all informative suggestions given at the end of the survey by participants.

5. DISCUSSION

Out of 71 participants, 28% answered that they had not heard of CCE, while 72% showed that they had. From the postgraduates, 16% had said no but in comparison to the group of students, 34.78% had said no. This shows that more students were unaware of CCE, and postgraduates were more aware of the subject. The reason for that could be more experience, and exposure.

32% of all participants said they knew CCE 'through individual research', while 40% said they knew it through 'University (higher education)' and 12% said they knew it through working. This manifests that participants learnt of CCE more through education and through their own research then working in the industry. This is promising, as students, and postgraduates were introduced to CCE in some form of education. Only 8% less however chose 'through individual research' which means that a reasonable percentage did their own investigation of the topic.

The participants were then asked to rate their confidence on their knowledge of CCE. 9% more students than postgraduates chose 'very poor'. 13% more postgraduates said their knowledge was 'poor'. 22% more students said their knowledge was average. Out of 'good' and 'excellent' 12% more postgraduates said their knowledge was 'good' and 6% more postgraduates said they were very confident. This appears that although current students are aware of the subject and have been introduced to it, the majority feel like their knowledge is 'very poor' to 'average'. Out of the postgraduates, only 20% had chosen they felt confident on CCE and for students only 6% said they were confident. This shows awareness of CCE, but not a good level of understanding. This is however some form of improvement, compared to the data given from the Manchester survey pre the Interdisciplinary module it stated that 71% students had previous knowledge of sustainable development, but of those only 33% of students have heard of the CE and unsure and the remaining 67% of students have never heard of it. This may be because the topic has had more time to circulate and gain more momentum over the period (from 2008 to 2022).

The participants were then asked to checkbox how many CCE principles they were aware of. Out of the pool of students, the majority (36.96%) knew only 1 policy, however with the postgraduates their majority (28%) knew 2 principles. Around 9.83% more postgraduates than current students knew all 5 principles named. The reasons for this can be a difference of experience, and exposure to more information on CCE. This suggests that postgraduates and people already in the working industry knew more about CCE which is understandable given more time, research, and exposure. It does suggest that students did not have a lot of information on the principles of CCE.

When asked to rank the challenges faced by the implementation of CCE, postgraduates' most common answer was 'Unclear Financial case for clients and stakeholders'. For students the most common answer was 'Raising awareness for CCE in Industry & Education'. Given the greater experience in the industry, it is understandable why this was the most common answer recorded. There is a strong challenge of creating a clear financial incentive for private funders of infrastructure. There are documents addressing the issue of creating a financial justification for sustainable construction such as 'Sustainable Construction: Clients' (Sustainable Construction: Clients). This entails why sustainable construction with no site waste is important and touches upon different types of sustainability. One of the largest challenges for adopting circularity in the built environment is the unclear financial case, which ranked number one for many stakeholders; having a clear business case was the most important enabler (Adams et al, 2017). Student's feel that CCE should be encouraged and developed. This would be because according to the survey results, most students did not feel confident on their knowledge on CCE. It is still in its infancy of application, and although sustainable development has been included in many course requirements.

Feedback given by both groups of people named the key words for creating progression of awareness in CCE are given in Table 5 below with relevant studies and sources.

Table 4 - Key words given by survey participants, with progress made and sources

Key Words	Progress prior & Analysis	Sources
Government	<p>Circular Economy Package statement – This sets out a policy framework for the production stage, giving producers a roadmap of how we will double resource productivity and achieve zero avoidable waste by 2050.</p> <p>Industrial Strategy – Sets out the aim of broader outcomes to be considered at the design stage of major projects.</p> <p>Resources and Waste Strategy (RWS) – This demonstrates ambition to move to a more circular economy which will see keeping resources in use, while extracting maximum value and promoting efficiency.</p>	<p>(A Green Future: Our 25-year Plan to Improve the Environment, 2018)</p> <p>(Industrial Strategy, 2018)</p> <p>(OUR WASTE, OUR RESOURCES: A STRATEGY FOR ENGLAND, 2018)</p>
Seminars	<p>Concrete EXPO (May 2022) – This Expo will consist of seminars including 'Circular Economy for Mineral-based construction materials', and 'Steel Circularity – From Consumption to regeneration' (Future Work)</p>	<p>(Seminars - Concrete EXPO)</p>
Conferences	<p>Symposium 5: The Circular Economy - The theme was The Circular Economy explored through sub-themes of Designing for Circularity, Learning from Natural Systems, and Dematerialisation.</p> <p>1st International Conference on Construction Circular Economy – The aim of the conference was to bring together</p>	<p>('Frontiers of Engineering for Development symposium: The Circular Economy', 2018)</p>

	construction industry positions to identify future challenges and to devise new methods of working to speed up the transformative journey on the CE.	(‘ASBP at 1st International Conference on Construction Circular Economy’, 2019)
Awareness	ICE: Circular economy in construction: current awareness, challenges, and enablers – This paper provides an analysis of an industry wide perspective of circular economy awareness, challenges, and enablers. This is awareness on an industry level.	(Adams, Osmani, Thorpe and Thornback, 2017)
Campaigns	A few of many institutions are campaigning for CCE: <ul style="list-style-type: none"> - ICE: Infrastructure and the circular economy - SNC Lavalin: Civil Engineering and the Circular Economy - ARUP: The Circular Economy - Ellen Macarthur Foundation: Driving the circular economy on a university campus 	(‘The Carbon Project: infrastructure and the circular economy’, 2021) (‘Civil engineering and the circular economy’, 2021) (FROM PRINCIPLES TO PRACTICES: REALISING THE VALUE OF CIRCULAR ECONOMY IN REAL ESTATE, 2020) (‘Driving the circular economy on a university campus’)
CPD (Continual Professional Development)	CPD for Civil and Structural Engineers – CPD is a learning activity that enables an engineering professional to develop their competencies, and CPD activities, training and examples are given.	(‘CPD for Civil and Structural Engineers’, 2019)
Policy Framework	The Rise of the Circular Economy BS 8001 – Framework for implanting the principles of the circular economy in organisations – guide.	(‘Framework for implementing the principles of the circular economy in organizations – Guide’, 2017)
Project/practical examples	JLL: Landmark Office Manchester - Circular principles being addressed: Reuse (including refurbishment and repurpose) / Design buildings for flexibility and optimisation. Gilbert Ash: UCL School of Architecture – CCE principles being addressed: Reuse (including refurbishment and repurpose) / Design buildings for flexibility and optimisation / Design and construct responsibility.	All case studies can be accessed on: (ADVANCING CIRCULAR CONSTRUCTION, 2020)

5.1. Current challenges in the implementation of CCE

One of the two main challenges in the implementation of CCE in higher education is related to the cultural mindset and course requirements. Participants still may not feel confident about their knowledge of CCE. This can be stemmed from not being taught in depth at universities and can be linked back to the learning outcomes provided by different institutions which are made and approved by the Engineering Accreditation Board. Culturally speaking the political decision makers should see CCE as an opportunity, and in turn this will filter into the higher education systems. The time has come for this branch of Sustainability to be considered as an important part of the curriculum. This is classified as a barrier for the lack of knowledge in the area.

Another challenge is the lack of personalised student journeys for CCE. The Circular Economy has been taught in some forms throughout higher education, which is why it was highly rated as the source of information on the survey. This may not however be specific to civil engineers. Personalised learning refers to a diverse variety of educational programmes that are intended to address the distinct learning needs, interests, or aspirations of individual students. Although the ISD module was designed to span disciplinary boundaries, so that no students would be

unfairly advantaged or disadvantaged because of their discipline, it can be suggested that if this was applied to the course requirements for this type of engineering that it should be more built upon and catered with more examples of real situations for civil engineers. It is hard to implement a topic for one body of students, however a suggestion would be if a survey was done before the modules beginning what kind of students were interested, then case studies or interactive activities can be based on their personalised journeys.

5.2. Suggested solutions to encourage progression of awareness of CCE

Following the results presented above, recommendations can be suggested on three different themes, namely short course / professional course, campaigns and conferences on CCE, and promotion of existing cases and frameworks to companies / higher education institutions.

Short course / professional course:

One way of introducing CCE principles into higher education is to apply a short course module to second-third year undergrad and post grad students with alike learning outcomes to that of the ISD module and CCE module in University of Strathclyde. Short courses are a great way to fill the gaps in professional knowledge. The application of this will require staff, resources, and funding but given different institutional support such as the RAEng or the Ellen Macarthur Foundation, this can be a possibility.

Campaigns and conferences on CCE

From the Symposium on CCE done by the RAEng, 88.24% responders answered that the overall event was excellent while 11.76% answered good. This shows very positive feedback, and from the qualitative data it was shown that people appreciated CCE event. The overall feedback on the sessions were generally positive, with majority of answers being excellent for all the topics. A recommendation derived from the online survey is promoting through social media. Using social media is a great way to campaign and is a very easy way to track success rates with immediate qualitative feedback. As shown in Table 5 there have been several conferences and campaigns shining a light on the topic.

Promotion of existing cases and frameworks to companies / higher education institutions

Arup and the Ellen MacArthur foundation launched a toolkit (Circular Buildings Toolkit) in a bid to bring the Circular Economy for buildings into the mainstream, and future-proof assets in the face of a rapidly changing policy landscape. The toolkit has taken the principles of the Circular Economy and translated them into a prioritised set of strategies and actions relevant for real estate projects. Alongside circular building guidance are real-life examples of how building design and operation can utilise the principles of the circular economy, with relevant case studies from recent projects ('Circular Buildings Toolkit'). They specify that the toolkit is free to use and open to all and will remain live. It will be a constantly updated resource showing practical learnings from the latest circular projects around the world and can be accessed here: <https://ce-toolkit.dhub.arup.com/>

Tomkinson et al (2016) stated that "student feedback suggests that students, including engineers, are willing to learn more about and for an economy that is increasingly gaining

momentum”. In our survey, 73% of students agreed with the fact of ‘Sustainable development is something which all courses should actively incorporate and promote’ (Students Organising for Sustainability International). As mentioned above, the Manchester survey on the ISD module said that feedback scores had been positive for every aspect of the module.

6. CONCLUSION

Circular Civil Engineering (CCE) is applying circular economy principles to engineering, but it has its challenges. The construction industry is currently in a linear system and the more exposure on this topic, the more minds can come together to create new ways of designing buildings for adaptability, deconstruction, and reuse.

The main aim of this research was to analyse if any progression has been made on the awareness of this subject by conducting a survey and making comparisons between levels of awareness in each party. Results show students and postgraduates to be aware of the subject, but both parties having low confidence in their knowledge. Postgraduates felt more confident, but there was not a large percentage difference.

Some of the main barriers against progression would be lack of course requirements promoting CCE, and lack of compulsory learning objectives on addressing it by Institutions and the JBM. Another barrier named was the lack of student personalisation for CCE teaching; The

Circular Economy is not a new concept, but in terms of applying it to civil engineering it is easier to learn given real case studies and construction-phase situations which civil engineers would be faced with.

Some of the limitations of this study It is important to note that most of the respondents were from the Bristol area, which may have affected the validity of the conclusions across the UK. However, the responses received from other areas show that conclusions are likely to be valid for other areas in the UK. The reason for why this data may be uncertain is that because it’s mostly from the same geographical area it doesn’t provide a broad range of data (e.g., opinions, beliefs, values, factual).

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