

How to understand and teach upcycling in the context of the circular economy: Literature review and first phase of Delphi

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Abstract: Transitioning from a linear economy to a circular economy (CE) requires changes in education at all levels, especially in higher education. The changes in education for the transformation towards CE in both formal and informal settings will eventually inform, inspire, and affect professional practices in industries in a positive way. Aligned with CE, a promising umbrella concept and practice called ‘upcycling’ is emerging. The concepts and practices of CE and upcycling overlap depending on the diverse definitions of the terms provided by academics and practitioners in various disciplines and sectors in different parts of the world. This has caused some confusions and misunderstanding by some academics and professionals. For teachers and training providers that aim to teach students and professionals about sustainable production and consumption including upcycling and CE, it is beneficial to distinguish between these two concepts. Understanding the interrelationships between them in theory and practice is important to provide researchers and practitioners with a clear guidance and recommendations. This study aimed to explore how we should understand and teach upcycling in the context of CE utilising a Delphi method. This short paper presents the literature review and preliminary analysis results based on the first phase of Delphi: definitions of upcycling and CE, comparisons between upcycling and CE, upcycling as part of CE (or interrelationships between them), and effective ways to communicate the aforementioned contents.

Introduction

Transitioning from a linear economy (based on take, make, use, and dispose) to a circular economy (CE) (sustainable alternative system based on material circularity (Stahel, 2016)) requires changes in education at all levels, especially in higher education (Kirchherr & Piscicelli, 2019). The changes in education for the transformation towards CE in both formal and informal settings will eventually inform, inspire, and affect professional practices in industries in a positive way (Rokicki et al., 2020; Salas, Criollo, & Ramirez, 2021). Aligned with CE, a promising umbrella concept and practice called ‘upcycling’ is emerging. Upcycling is an approach to extending the lifetimes of products, components and materials by utilising various

CE practices (e.g., ‘creative’ repair, reuse, refurbishment, redesign, and remanufacturing) to create a product/material of higher quality or value than the compositional elements (i.e., used or waste products, components and/or materials) (Singh, Sung, Cooper, West, & Mont, 2019; Sung, 2017). The concepts of and practices in CE and upcycling overlap depending on the diverse definitions of the terms provided by academics and practitioners in various disciplines and sectors in different parts of the world (e.g., Bridgens et al., 2018; Kalmykova, Sadagopan, & Rosado, 2018; MacArthur, 2013; Sung, 2015). According to multiple anecdotal evidences, this has caused some confusions and misunderstanding by some academics and professionals. For

teachers and training providers that aim to teach students and professionals about sustainable production and consumption including upcycling and CE, it would be beneficial to distinguish between these two concepts. Understanding the interrelationships between them in theory and practice is important to provide researchers and practitioners with a clear guidance and recommendations. This study aimed to explore how we should understand and teach upcycling in the context of CE (with the ultimate goal of contributing to the transition to CE) utilising a Delphi method (a series of questionnaires with experts) (Ziglio, 1996).

Project background

The starting point of this study was the British Science Festival 2022 event, 'Upcycling Station', at Leicester's Creative Business (LCB) Depot in Leicester, UK in September 2022. This event was initiated and co-organised by the first author and Dr Mary O'Neill at De Montfort University. Nine global experts in upcycling and CE from academia and industry who are part of the International Upcycling Research Network (funded by UKRI-UK Research and Innovation – AHRC-Arts and Humanities Research Council) made short videos to explain what upcycling is and how it is related to CE to inform and educate the general public. The AHRC-funded International Upcycling Research Network project is run by the first (PI) and second (Co-I) authors. The initial idea was to use the video resources as the basis for developing educational materials for wider dissemination. However, taking into account the limited number of participants and the diversity of the contents, we decided to develop this into a research project involving literature review and Delphi in order to develop more comprehensive and valid educational materials reflecting a wide range of sources of information and expertise.

Methods

We conducted a literature review between October and November 2022. Using the literature review outcomes, we carried out the first phase of Delphi between February and March 2023.

Literature review

Theoretical, narrative review (Paré, Trudel, Jaana, & Kitsiou, 2015) was conducted using one bibliographic database – Google Scholar –

selected for sufficient coverage (Halevi, Moed, & Bar-Ilan, 2017). "Upcycling" and "circular economy" (not as combination) were used as search keywords. We only included journal articles, conference proceedings, and PhD theses written in English using the first 60 search outcomes (first 6 pages) as the arbitrary cut-off point (no other inclusion or exclusion criteria). From this first screening process, we identified 58 upcycling publications (52 journal articles, 5 conference proceedings, and 1 PhD thesis), and 50 CE journal articles. We then checked titles, abstracts and main body for the content relevance (second screening). During the content screening, we excluded publications that lack theoretical description or discussion on the concept of upcycling or CE, resulting in 52 upcycling literature (46 journal articles, 5 conference proceedings, and 1 PhD thesis) and 42 CE journal articles (to be reviewed). We analysed and discussed the contents in terms of definition and concept of upcycling and CE, comparison between them, and their interrelationships. Detailed review methods and processes can be found in the separate review paper, 'Understanding upcycling and circular economy and their interrelationships through literature review for design education' (Sung, 2023).

First phase of Delphi

We designed the Delphi study questionnaire based on the literature review results and asked study participants, 'What would you like to add, change, delete, or improve from the description/table/diagram below?' in terms of definition of upcycling and CE (descriptions), comparison between upcycling and CE (table), and upcycling as part of CE (diagram). There were two additional questions. One was 'What would be the effective ways to communicate the above information (how to define upcycling and circular economy, the comparison between them, and the interrelationship between them) for educational purposes? (e.g., for UG, PGT, or PGR students, industry professionals)' as an open-ended question. The other was 'Please rate your level of confidence that your contribution is accurate below' with five answer options: (i) 99-80% confidence in being right; (ii) 79-60% confidence; (iii) 59-40% confidence; (iv) 39-20% confidence; and (v) 19-0% confidence.

The questionnaire (word document) was sent via email to 46 experts (academics and practitioners) in upcycling and CE who are part



of the AHRC-funded International Upcycling Research Network. 15 people (14 academics and 1 practitioner) responded (32.61% response rate) as email reply. They are from 10 different countries of 4 continents (Australia, Botswana, Brazil, Costa Rica, Ghana, Kenya, Sweden, UK, USA, Zimbabwe); 8 females and 7 males. As an incentive to increase the participation rate and as a token of gratitude, three randomly selected participants received £10 Amazon e-voucher.

Results

Literature review

To summarise the review (based on 52 upcycling literature), upcycling was largely described as an effective design-based solution and green practice:

- utilising the materials, components and products that are discarded, no longer in use or about to be disposed of.
- incorporating multiple material processes (e.g., 'creative' or 'innovative' reuse, repurpose, repair, upgrade, redesign, reconstruction, refashion, remanufacture, and advanced recycling) involving minimisation of waste and toxicity, saving in energy and water, reduction in emissions and pollution.
- creating the outputs of new/modified products and materials with higher quality and values (economic, aesthetic, and environmental) than the original or compositional elements.

Circular economy (based on 42 reviewed CE journal articles) was largely illustrated as an alternative economic model and industrial system of production and consumption designed to be restorative or regenerative by:

- (i) restructuring the material flows from the linear approach (take, make use, and dispose of) to the circular one (e.g., slowing and closing resource loops or narrowing resource flows); (ii) relying on renewable energy, (iii) minimising, tracking and eliminating the use of toxic chemicals, (iv) utilising applicable principles (e.g., refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover), and (v) actioning in circular product design and production, business models, technology development, cross-cycle and cross-sector collaboration, and supportive environment including policies conducive to CE.

- operated in micro (enterprises and consumers), meso (economic agents in symbiosis), and macro (cities, regions, and governments) levels.
- resulting in environmental benefits such as increased resource/material efficiency and reduced wastes and emissions, as well as socio-economic benefits such as reduced costs for raw materials, energy, waste management and emissions control, and new employment opportunities.

Upcycling	CE
What	
Effective, design-based solution and a green practice.	An alternative economic model and industrial system of production and consumption designed to be restorative or regenerative.
Input materials	
The materials, components and products that are discarded, no longer in use or about to be disposed of.	Virgin and synthetic materials, components and products that are discarded, and no longer in use or about to be disposed of.
Principles or practices	
'Creative' or 'innovative' reuse, repurpose, repair, upgrade, redesign, reconstruction, refashion, remanufacture, advanced recycling, and more.	Refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover and more.
How	
<ul style="list-style-type: none"> - Minimising waste and toxicity. - Saving energy and water. - Reducing emissions and pollution. 	<ul style="list-style-type: none"> - Restructuring the material flows from the linear approach (take, make use, and dispose of) to the circular one (e.g., slowing and closing resource loops or narrowing resource flows). - Relying on renewable energy. - Minimising, tracking, and eliminating the use of toxic chemicals. - Actioning in circular product design and production, business models, technology development, cross-cycle and cross-sector collaboration, and supportive environment, including policies conducive to CE.
Outcome	
New/modified products and materials with higher quality and values (economic, aesthetic, environmental) than the original/compositional elements.	<ul style="list-style-type: none"> - New/improved policies, regulations, guidelines, or governance systems. - New/improved partnerships or collaborations (industrial symbiosis). - New/improved business models. - New/improved supply chain management systems. - New/improved production or manufacturing systems. - New products for long-life. - New products for product-life extension. - New biodegradable products. - New products using fewer resources. - Sharing or leasing services (renting, pooling). - Product service system. - New/improved reuse initiatives (e.g., second-hand shops). - Incentivised product return service. - Upgraded products. - Remanufactured or refurbished products and parts. - Repaired products. - Recycled materials. - Recovered energy. - ...
Operation	
In micro (enterprises and consumers) and meso (economic agents in symbiosis) levels	In micro (enterprises and consumers), meso (economic agents in symbiosis), and macro (cities, regions, and governments) levels

Table 1. Comparison between upcycling and CE

We compared between upcycling and CE concepts (Table 1), and realised that the benefits (or end goals) are the same. The common benefits include:

- Environmental benefits such as increased resource/material efficiency and reduced waste and emissions.
- Socio-economic benefits such as reduced costs for raw materials, energy, waste management, emissions control, and new employment opportunities.

From the synthesis of the literature review, we created a diagram to show upcycling as part of CE (or interrelationships between them) (Figure 1). The comprehensive literature review results can be found in the review paper (Sung, 2023).

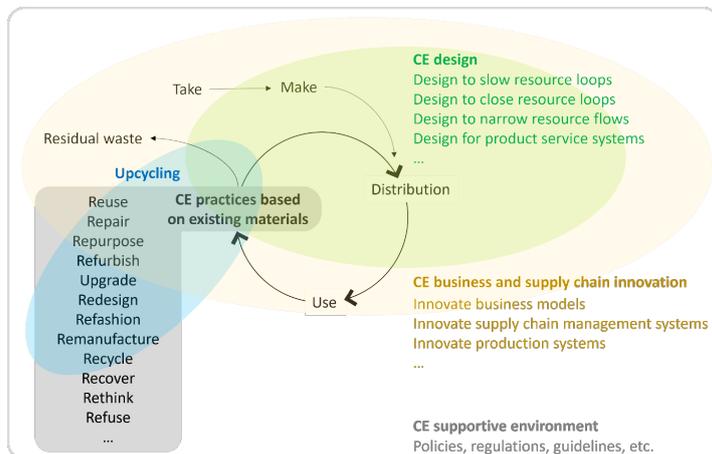


Figure 1. Upcycling as part of CE

First phase of Delphi

The responses (from 15 study participants) were collated and the following revisions and suggestions were made.

Regarding the definition and description of upcycling, most responding experts agreed that upcycling could potentially be an effective design- or process-based solution and sustainable practice to avoid the use of virgin materials:

- Utilising the materials, components and products that are discarded, no longer in use, rarely utilised or about to be disposed of (using both pre- and post-consumer solid waste) and giving them a new purpose
- Utilising material processes/methods (e.g. 'creative' or 'innovative' reuse, repurpose, repair, upgrading, redesign, reconstruction, refashion, remanufacture) involving minimisation of waste and ideally systematic efforts for elimination of toxicity,

saving in energy and water, and reduction in emissions and pollution

- Creating the outputs of new/modified products (or artefacts) and materials with higher quality and values (economic, aesthetic, environmental, cultural, and social) than the compositional elements, and creating multiple use cycles of products, components and materials in upcycled products
- Generating alternative consumption and production local systems with strong socio-environmental values that can integrate and reconnect communities and intergenerational relations around sustainable practices
- Oftentimes reclaiming traditional knowledge and skills (e.g. handcrafts, repair, repurpose) and establishing a set of socioenvironmental values around these social practices

Regarding the definition and description of CE, the experts mostly agreed that the circular economy is an alternative, sustainable economic model and production and consumption system intentionally designed to be restorative or regenerative by:

- (i) restructuring the material flows from the linear approach (take, make, use and dispose) to the circular one (slowing and closing resource loops, and narrowing and facilitating resource flows); (ii) relying on distributed renewable sources of energy; (iii) minimising, tracking and eliminating the use of toxic chemicals; (iv) utilising applicable principles (e.g. refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, regenerate, repurpose, recycle, recover); (v) actioning in circular product design and production, business models, technology development, cross-cycle and cross-sector collaboration, and supportive and equitable environment including policies conducive to CE; (vi) facilitating the inclusion of practices that foster social justice; and (vii) educating the future generations
- Operated across scales including micro (enterprises and consumers), meso (economic agents and enterprises in symbiosis), and macro (cities, regions, and governments) levels
- Resulting in environmental benefits such as increased resource/material efficiency and reduced wastes and emissions, as well as socio-economic benefits such as reduced

costs for raw materials, energy, waste management and emissions control, new employment and/or social opportunities, and individuals' sustainable consumption and lifestyles

Regarding the comparison between upcycling and CE, one critical feedback was that as upcycling is part of CE, they are not at the same level and therefore incomparable. The comparison table will need to be radically restructured in such a way that in each category CE description incorporates upcycling description as part, which is one of the next steps beyond the remit of this paper.

Regarding the diagram to show the interrelationship between upcycling and CE, some additions and revisions were made on the basis of the participating experts' feedback as seen in Figure 2. The main change was in CE environment.

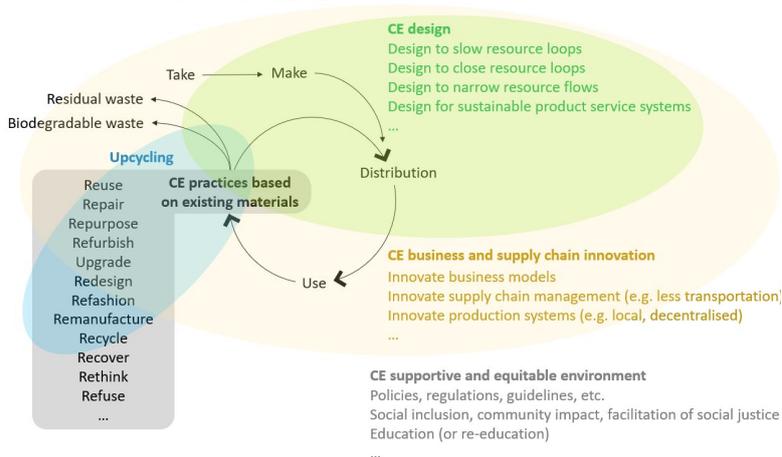


Figure 2. Upcycling as part of CE revised

Regarding the effective ways to communicate the upcycling and CE information for educational purposes, the respondents suggested:

- Demonstration video to talk through the diagram or animated diagram (n=5)
- Visual and written information as training manuals or toolkits in the form of paper, book chapter, poster, etc. (soft and hard copies) (n=2)
- The suggested diagram would work well (n=2)
- Interactive session where learners can give their opinions/ideas
- Hands-on upcycling example activities and competitions
- Research project involving upcycling
- Real-life projects, workshops, seminars

- Symposium or conference
- Exhibitions with thought-provoking images and artefacts
- Breaking down the contents into sub systems (e.g. take, make, distribution, use)
- Focusing on similarities than differences

The respondents' confidence rate was mostly 99-80% confidence in being right (n=10; 66.67%), followed by 79-60% confidence in being right (n=4; 26.67%), and 39-20% confidence in being right (n=1; 6.67%).

Conclusions

The first phase of Delphi results showed that the participating experts provided diversified and critical comments and feedback on the given descriptions and diagram. There is no consensus made yet which will be achieved throughout the further iterations of the questionnaire with the same expert panel in the future. This is obviously work in progress and hopefully we reach the consensus soon to confirm the contents. Once contents are confirmed, we will create a short animation video to explain the concepts of upcycling and CE and their interrelationships using the final diagram. Training manual/toolkit will be published as an open access digital document that can be freely downloaded by anyone. We hope that by end of this project we have something substantial to contribute to design education for transitioning towards the circular economy.

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