# Business experimentation for a circular economy - Learning in the front end of innovation

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| **Abstract:** | Business experimentation has been recognized as an important means for accelerating transitions towards a circular economy (CE). This paper aims to develop a new understanding of how learning from business experiments at the front end of innovation may help develop ideas and concepts that can advance a CE. The study adopts a case study approach and investigates four experiments conducted by a single organization in the context of recycling. The learning outcomes of these experiments are examined by using the lens of learning loops. Single loop learning refers to detecting and correcting errors in existing policies. In double loop learning underlying assumptions are questioned and new policies are formulated. In triple loop learning, entirely new processes and methodologies for problem solving are devised. We conclude that incremental ideas associated with single loop learning may be insufficient for a CE. While radical ideas associated with double loop learning may be critical for a CE, double loop learning may require designing the experiments to address CE innovation challenges. We propose that focusing on triple loop learning may be the answer, and by examining the relationships between the different forms of learning and CE innovation challenges, we determine which type of learning was best suited to overcoming these challenges. Further, this study elaborates the concept of learning loops in the context of front end of CE innovation by identifying 11 forms of learning from experiments. For managers, the study offers insights on how the experimentation process should be developed to overcome the barriers to CE innovation. |

Dear Ilka
Many thanks for the opportunity to revise our paper. We have carefully considered the comments by the reviewers, and modified the text accordingly, shortened the paper and ensure clarity and consistency of terminology used.

Please find attached slightly modified highlights – as I don't find a place for them in the manuscript system

Best regards
Anna Aminoff and Matti Pihlajamaa

Highlights

- Investigates learning from circular business experiments in the front of innovation
- Adopts the concept of learning loops for analysing the outcomes of the experiments.
- Identifies 11 distinct forms of learning that are categorized into three groups: single, double, and triple loop learning.
- Explains the roles of learning loops in advancing a CE.
- Gives practical insights on how to design business experiments to overcome CE innovation challenges.

**Response to reviewers: Business experimentation for a circular economy - Learning in the front end of innovation**

The authors would like to thank the reviewers for their valuable comments on how to improve our manuscript. We have considered each comment carefully and revised the manuscript accordingly.

Thank you for the opportunity to improve our research.

Dear authors,

Thank you for submitting this substantially improved manuscript. We are happy to let you know that this requires minor revisions and, in particular, we ask you to ensure clarity and consistency of terminology used. As second point, please ensure that the manuscript does not exceed 9500 words, already 1500 words over the limit mentioned in the author guidelines. I was very surprised to see the word count well above 10,000, especially after previously referring you to author guidance and explicitly mentioning the 8000 words MAXIMUM word limit for research articles.

Please submit the final version of the article in 3 weeks time [i.e. by 23 August 2020].

With kind regards,
Ilka Weissbrod, also on behalf of fellow guest editors Nancy Bocken and Maria Antikainen

*Authors' response:*
*Many thanks for the opportunity to revise our paper. We have carefully considered the comments by the reviewers, and modified the text accordingly, shortened the paper and ensure clarity and consistency of terminology used.*

**Reviewer #1: Dear authors,**

Thanks for reviewing the manuscript, which is now well structured and more solid. I enjoyed reading it and was glad to find radical improvements from the previous version, based on the provided feedback. I recommend an additional round of minor revision before the article can be published. This is mostly related to minor issues, and importantly, to the discussion section, which in my view is not up to mark yet. To this end, please find my comments below.

*Authors' response:*
*Many thanks for the valuable feedback and recommendations during the process.*

ABSTRACT
Please explain what single, double and triple loop means otherwise readers might struggle to understand the contribution of the paper.

*Authors' response:*
*We have modified the abstract and added the explanation of single, double and triple loops.*

INTRODUCTION

Thank you for improving this section, which is now sharp and to the point. I suggest to:

- At the end of paragraph 3 you state that learning in the front end is likely to be different from the later phases. I find this somehow vague. Please clearly explain how that is different and why it is problematic.

*Authors' response:*
*We have clarified this issue by stating that "Learning in this front-end phase is, however, likely to be different from the later phases as it addresses the generation of new ideas whose potential and feasibility may be difficult to evaluate". We also emphasize the 'fuzzy' and 'chaotic' nature of the front end phase which makes the generation of especially radical ideas difficult to manage.*

- At the beginning of paragraph 4 of the intro there is a mistake. "The research gap that our study addresses is that (THERE) despite the value…" Please proofread the document and make sure that it is free of such mistakes. While reading the text I found more typos (e.g. Reis 2011, instead of Ries in section 2.2) and mistakes showing that, despite repeated comments on the issue, the paper has not been properly proofread yet. Please proofread the document thoroughly in order to make it publishable.

*Authors' response:*
*We are sorry for these mistakes. The paper was carefully proofread by the professional in the previous round (after the review round 2), but there have been modifications after that. The latest version manuscript has now been thoroughly proofread.*

- In paragraph 4, the sentence where you state the gap needs referencing. Furthermore, I strongly recommend adding a couple more sentences elaborating on the gap. This will improve the positioning of your relevant paper.

*Authors' response:*
*We have revised paragraph 4 by including material from the previous paragraph that elaborates the gap and supports it with references.*

LITERATURE REVIEW

Thank you for improving this section. I suggest to:
- In 2.1 you state that literature on CE experimentation is still very narrow, citing the work of key authors, including Bocken, Weissbrod and Antikainen. While I agree that this stream of literature is stil in its infancy and therefore narrow, I am also aware of many more scholars working in this space, next to those you already mention. I suggest to refer to their work as a way to acknowledge their efforts and more importantly to add more diversity in your sources, ultimately showing that you have thoroughly reviewed this literature stream.

*Authors' response:*
*This is a valid point. We have added a few more references to CE and business experimentation, including Aagaard et forthcoming), al Konietzko et al (forthcoming), Buhl et al. (2019); Andries et al (2013).*

*Comment:*
- 2.2 repeats many things that have already been said in 2.1, including many sources about CE experimentation. I saw the comment of the other reviewer concerning the need of deepening your review on organizational learning and agree with him. Therefore, I suggest to focus this section more on organizational learning, while making it more concise and merging it with 2.2.1, which is where you provide the insights that are most relevant for your work.

*Authors' response:*
*We also noticed that there was some repetition. We have reorganised the section 2 to make it less repetitive.*

*Comment:*
- I suggest to have 2.1 and 2.2 more or less equal in length, to display a comparable level of depth in the two areas of your review.

*Authors' response:*
*To increase clarity, we divided the literature review into subsections, and these are more or less equal in length.*

METHOD
This section is now clear and well structured. Agree that a figure is not strictly needed. While I leave the choice of adding a simple figure up to you, please consider that visualizing would help for the reader to move quicker through the section.

*Authors' response:*
*We agree that a figure could be beneficial, but as the manuscript is already overly lengthy, we decided not to add new material in the method section.*

RESULTS

Thanks for improving this section, which is not more clear, therefore insightful. Below some minor suggestions to improve it further.

- Table 1 could be moved up front, between section 4 and 4.1, as  way to anticipate to the reader what is coming. This will improve readability. Also I suggest to format in bold (or italic or underscore) the 11 categories inside the table to further increase its readability.

*Authors' response:*
*We followed this suggestion and moved the Table between sections 4 and 4.1 and formatted the 11 categories in italic.*

*Comment:*
- In 4.4 you talk about key challenges, that are also summarized and presented in figure 2. I find this a very interesting part of your results. Yet, you do not mention it at all in the abstract. I suggest to incorporate these insights in the abstract to hook readers into your paper and increase the impact of your work. For the same reason, I would explicitly state your contributions to theory and implications for practice in the abstract.

*Authors' response:*
*We have added both the CE challenges as well as implications to the theory and practice to the abstract.*

DISCUSSION

This section has improved, however additional improvements would make your paper more relevant. Please consider the comments below:
- Splitting the section in "5.1 contributions CE experimentation theory" and "5.2. implications for CE experimentation practice" would be helpful to walk readers more effectively through your contributions.

*Authors' response:*
*We split the discussion into two subsections to distinguish between our theoretical and practical contributions. To avoid repetition, we also combined the discussion and conclusions sections and added subsection 5.3 Limitations and future research.*

- The contributions to theory could be sharpened. In the current version of the paper I find many repetitions of things that have already been said. My suggestion would be to make it a bit more concise and at the same time incorporate some reflections related to the challenges identified in figure 2. This is a very relevant part of your results and it is not sufficiently discussed. Doing so, would increase the relevance of your contribution. Figure 3 would benefit from improvement as well, incorporating these thoughts in the visual to increase its relevance and level of insight.

*Authors' response:*
*The discussion is now more concise and compact, and repetition is removed.*
*Moreover, we have fine-tuned figure 3 and added figure 4 which focuses on how to overcome the CE innovation challenges.*

- I appreciate your advice to managers. In line with my previous comment, I suggest to sharpen it a little bit, elaborating on how they can overcome the challenges identified in figure 2.

*Authors' response:*
*We added a section that refers to figure 4 and suggests how it may inform managers to overcome CE innovation challenges by adjusting their experiment designs.*

CONCLUSION

- Limitations are properly identified and directions for future research are suggested. The latter could be improved by making them more aligned with the research gap you identified. It would be great if you could suggest future research directions more specifically related to learning. This would help other scholars to use and build upon your work.

*Authors' response:*
*We have strengthened the learning aspect in our discussion of future research opportunities, as you advised.*

*Comment:*

Reviewer #4: Thank you for this much improved paper!
Many of my comments have been resolved and the work has become much more digestible.
Below I highlight my outstanding revisions.

*Authors' response:*
*Many thanks for the valuable feedback and recommendations during the process.*

*Comment:*
Method:

3.1: add the timing of data collection and whether and why it was decided to anonymise the case.

End of section 3.1 - Sentence starting with: The research team followed... Would end with something like this:

.. "but did not have an active role in the development or roll-out of the experiments". This in response to my former comment asking whether the authors had an active role in the experiment set up and roll out.

*Authors' response:*

*Thank you for the suggestion. We have added these statements.*

**Results:**
I stumbled particularly over Section 4.4. Figure 2 (suggests to make it an easily formatted Table) is difficult to navigate and the text in this section must be made much more succinct to convey the key messages.

*Authors' response:*
*We have modified the text to make it easier to navigate, and also marked some pieces of text as italics to help to see the connection between text and Figure 2. Also, we have modified figure 2 to make it easier to read. We decided, however, not to radically shorten the text nor reduce the information from the figure, as reviewer 1 finds both the figure and text important.*

**Discussion:**
Mentions that there are 2 key contributions but Figure 3 seems to show 3 contributions. Please check/ improve.
Also the '3rd contribution' in Fig. 3 is confusing : "Contributes to double loop learning via insights on experimentation process and methodologies. Helps overcome CE innovation challenges." - why is it positioned next to triple loop learning if it talks about double loop learning? Please improve figure 3 + descriptions, arrows and contributions for clarity.

*Authors' response:*
*We have clarified the text and Figure 3 in the following ways:*
- *We modified the text so that the number of main contributions (2) that is mentioned does not directly refer to Figure 3.*
- *We rewrote the description of the box next to triple loop learning.*
- *We added a new description box that explains the arrow from triple loop learning to double loop learning. The point that we wish to make is that triple loop learning is beneficial for a CE in that it helps manager design such experiments that acknowledge CE innovation challenges. This, in turn, makes double loop learning possible..*

*Comment:*
Overall, the Discussion can be made more succinct and also better leverage the older learning literature: so what are the expected and unexpected results here?
Single loop learning is probably more naturally linked to incrementalism but this is hardly surprising from older literature. I would frame the discussion (and also earlier text in the literature background) more as follows: what is expected from the learning literature (links between these learning types and CE; in Literature background) and what are the new and surprising findings, and confirming findings here? (Discussion) I don't expect hypotheses in the beginning of the paper, but rather a better feel throughout of how learning and experimenting may be linked (which you partly do in Section 2) which would allow for a Discussion that goes a little deeper than the present one. So this probably indicates a few clarifying sentences need to be added to 2.2.1, perhaps at the end, while at the same time trying to make it all more succinct (a challenge!). This is more about finesse and making your paper more effective and convincing to the reader.

*Authors' response:*

*In the last paragraph of the Literature review, we draw from the organizational learning literature to explain what single, double and triple loop learning could mean in the context of experimentation. In short, we associate single loop learning with incremental innovation, double loop learning with radical innovation, and triple loop learning with the institutionalization of innovation management within an organization.*

*As explained with more clarity in the revised (and more succinct) discussion section, the ideas about single and double loop learning are confirmed. When it comes to triple loop learning, we contribute by emphasizing how it may address experiment design and provide insights on how experiment design may be used to overcome CE innovation challenges. This contrasts the older learning literature, where triple loop learning is associated with overcoming organizational barriers to innovation and experimentation.*

*Comment:*
Conclusion:

Line 38: "The study concludes that incremental ideas... " This conclusion is rather unsurprising and confirms probably the oldest learning literature. Would add something like this and also emphasise somewhere in the conclusions what the real unexpected / new findings were.

*Authors' response:*
*To save space, we have combined the conclusions with the discussion section.*

*Comment:*
Figures & Tables:
- Figure 1: needs a source/ sources to the relevant works it builds on

- Figure 2: is way too busy and would suggest formatting it more simply, also with less text, as a table

Length:

The paper is way too lengthy. Please try and make some reductions, in the busy figures/ tables (e.g. Fig 2), the Literature review and the Results (section 4) to improve readability and stay within normal journal article sizes.

*Authors' response:*
*We have significantly shortened the article, especially the literature review, discussion and conclusions sections. Reviewer #1 emphasizes the value of section 4.4. and Figure 2 and while we have shortened those parts, we have been careful not to omit key information from them.*

*Figure 1 builds on Cooper (2013) that is mentioned in the title of the figure: "Figure 1. Learning from experiments in different phases of the innovation process (modified from Cooper (2013))."*

# Business experimentation for a circular economy - Learning in the front end of innovation

Anna Aminoff[1*], Matti Pihlajamaa[2]

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## Abstract

Business experimentation has been recognized as an important means for accelerating transitions towards a circular economy (CE). This paper aims to develop a new understanding of how learning from business experiments at the front end of innovation may help develop ideas and concepts that can advance a CE. The study adopts a case study approach and investigates four experiments conducted by a single organization in the context of recycling. The learning outcomes of these experiments are examined by using the lens of learning loops. Single loop learning refers to detecting and correcting errors in existing policies. In double loop learning underlying assumptions are questioned and new policies are formulated. In triple loop learning, entirely new processes and methodologies for problem solving are devised. We conclude that incremental ideas associated with single loop learning may be insufficient for a CE. While radical ideas associated with double loop learning may be critical for a CE, double loop learning may require designing the experiments to address CE innovation challenges. We propose that focusing on triple loop learning may be the answer, and by examining the relationships between the different forms of learning and CE innovation challenges, we determine which type of learning was best suited to overcoming these challenges. Further, this study elaborates the concept of learning loops in the context of front end of CE innovation by identifying 11 forms of learning from experiments. For managers, the study offers insights on how the experimentation process should be developed to overcome the barriers to CE innovation.

Keywords: Business experimentation; innovation; circular economy; recycling; organizational learning

Word count: 9294 words

# 1. Introduction

As concerns about the growing global population and over-consumption of finite resources increase, it is apparent that today's linear "take, make and dispose" models can no longer be continued. A circular economy (CE) offers an alternative solution to these challenges (Blomsma & Brennan, 2017). The benefits of a CE are relatively well understood, and a CE has the potential to achieve a radically more sustainable society and economic growth (Blomsma & Brennan, 2017). However, there are few concrete examples of successful circular businesses, as CE is often hindered by the complexity of new technologies and the lack of innovations (Tura et al., 2019). Business experimentation has been recognized as an important way of accelerating CE innovation (Bocken et al., 2019; Brown et al. 2019; Buhl et al., 2019), which is defined as "the coordinated activities that integrate CE goals, principles and recovery strategies into technical and market-based innovations" (Brown et al., 2019, p. 18).

The value of business experimentation lies in that it is an effective and efficient method for organizational learning (Huber, 1991). By conducting experiments, organizations may acquire new knowledge that can be used to develop better innovations (McDonald & Eisenhardt, 2020). The process of innovation becomes a serial, iterative process where lessons learned from individual experiments enables organizations to redirect their further development efforts in the right direction (Lynn et al., 1996). Organizational learning is, however, not automatic, but it needs to be managed (McKee, 1992). To be able to manage the learning processes better, it is important to understand what kind of learning takes place in experiments.

In this study, we focus on learning from experiments in a particular phase of the innovation process, the front end of innovation, which refers to the early time period where new opportunities are identified and the potential of ideas is evaluated (Reid & de Brentani, 2004). This phase has great potential, as many decisions that are critical for overcoming barriers to a CE (Brown et al., 2019; Tura et al., 2019), e.g. decisions regarding design, target customers, and availability of resources, are made very early (Smith & Reinertsen, 1991). It is, however, also described as fuzzy and chaotic and difficult to manage – especially so if the aim is to generate radical ideas (Koen et al., 2002).

The research gap that our study addresses is that despite the value of business experiments in the front end for advancing a CE has been acknowledged, there is lack of understanding of what kind of learning takes place in this phase. Whereas most business experiments follow the lean startup approach that focuses on hypothesis testing in the later innovation process phases (Ries, 2011; Blank, 2013), in some cases the scope of business experimentation is extended to include opportunity identification and ideation (see Bocken et al. 2018; Bocken et al. 2013), which suggests that experiments may be valuable also in the front end of innovation. Learning in this front end phase is, however, likely to be different from the later phases as it addresses the generation of new ideas whose potential and feasibility may be difficult to evaluate (Bocken et al., 2018; Cooper, 2013).

Further, radical ideas may be particularly difficult to generate (Reid & de Brentani, 2004; Felin et al., in press). To address this gap, this paper aims to answer to the research question: how to learn from CE business experiments in the front end of innovation?

We adopt a case study approach and examine four experiments conducted by a single organization in the recycling context. To make sense of the data, we examine the learning outcomes of these experiments using the lens of *learning loops*. The idea behind learning loops is that organizational learning can be categorized into three loops (single, double, and triple loop) depending on the degree to which initial assumptions and frameworks are questioned (Gugerell & Zuidema, 2017; Lozano, 2014; McKee, 1992). Single loop learning refers to detecting and correcting errors in existing policies. In double loop learning, underlying assumptions are questioned and new policies are formulated. In triple loop learning, entirely new processes and methodologies for problem solving are devised.

The paper is structured as follows. First, we introduce the relevant literature on organization learning and CE business experimentation, front end of innovation, and learning loops. Then we describe the methods, data and case organization of our empirical study and present the results. Next, we discuss the relevance of the findings for researchers and practitioners. Finally, we describe the study's limitations and make recommendations for further research.

# 2. Literature review

## 2.1 Organizational learning

Previous research contends that experimentation enables organizational learning (McDonald and Eisenhardt, 2020) that is a key process by which companies respond to changes in their environment. The concept of organizational learning draws from the idea that organizational decision-making processes are based on rules, procedures, and routines that are used whether they lead to positive outcomes or not (Cyert & March, 1963). Through the process of organizational learning, the experiences of people within organizations may be translated into new knowledge that has the potential to influence organizations' behaviour. The process includes acquiring new knowledge from experiments, sharing the knowledge within the organization, interpreting and integrating it, and, finally, storing the new knowledge for future use (Huber, 1991). Organizational learning has been considered a key antecedent of innovation as it allows new products and services to be adapted to changing conditions, such as customer needs, technological developments, and regulatory frameworks (Wheelwright & Clark, 1992). It is important to note that learning needs to be managed; organizations need to develop skills and capabilities that ensure that experiments produce learning outcomes (McKee, 1992; Kogut & Zander, 1992). Moreover, different kinds of learning need to be managed differently (March, 1991).

## 2.2 Circular economy business experimentation

Experimentation has been recognized as an important way of accelerating the transition towards a CE (Antikainen & Bocken 2019; Bocken et al., 2018; Konietzko et al., 2020). CE business experimentation theory is rooted in more general business experimentation research (Chesbrough, 2010; McGrath, 2010; Ries, 2011). The purpose of business experimentation is to test assumptions about future business and to build its legitimacy among stakeholders with low resources and low costs (Aagaard et al., In press; Bocken et al., 2019; Buhl et al., 2019;). While experiments may vary, some common elements can be identified. First, experiments are a method for learning (Andries et al., 2013; Lynn et al., 1996). Second, experiments are relatively small in size and scope (Berkhout et al., 2010; Brown & Vergragt, 2008). Third, experiments can help engage potential customers and other stakeholders (Bojovic et al., 2018, Bocken et al., 2019). This is important as sustainable value and circularity can be achieved only in collaboration with actors from the value chain and the wider system (Aalgaard et al., In press; Buhl et al., 2019).

Perhaps the most widely-diffused practitioner approach to experimentation is the so-called "lean startup" (Ries, 2011; Blank, 2013). In the lean startup approach, experimentation is understood as an iterative process to reduce uncertainties, engage stakeholders and promote collective learning (Bocken & Snihur, in press). It proceeds via build-measure-learn loops where an experiment is designed, its effects are measured, and the outcomes are reflected and internalized (Ries, 2011). The key elements of such learning are that it is deliberate and collective. Deliberation refers to having a learning focus while conducting experiments, typically by testing predefined hypotheses (Bocken et al., 2018). Collectiveness concerns the involvement of potential customers and other stakeholders to support learning (Bojovic et al., 2018, Bocken et al., 2019). Felin et al. (in press) criticize this approach in that it promotes incremental experiments that are insufficient for a CE, which requires radical departures from existing systems (Bocken et al., 2018; Weissbrod & Bocken, 2017). To promote a CE, business experiments should aim for outcomes that go beyond the existing dominant logics for developing new business (Bessant et al., 2014). Some authors, however, propose that experiments can be an effective method of searching for radically new solutions as they enable bounded environments for exploration that are not determined by organizations' existing competence endowments and path dependence (Bocken & Snihur, in press; Brown et al., 2019). Further, Weissbrod and Bocken (2017), emphasize that unplanned action-based learning from experiments in addition to deliberate learning is important.

## 2.3 Front end of innovation

In this paper, we choose to focus on learning in a particular phase of the innovation process: the front end of innovation, which refers to the early time period where new opportunities are identified, the potential of ideas is evaluated and ideas are developed into concepts and hypotheses (Reid & de Brentani, 2004). It is often characterized as fuzzy: chaotic, unpredictable, and unstructured (Koen et al. 2002). Smith and Reinertsen (1991) argue that the innovation process improvements that target the front end have the greatest potential for improving innovation outcomes for two reasons. First, many critical decisions regarding target customers, availability of resources, and alignment with corporate strategy are made very early. Second, the front end phase is often neglected by managers.

Lean startup implies a focus on the later innovation process phases (Bocken & Snihur, in press) as illustrated in Figure 1. However, some previous studies on business experimentation address the front end phase. Weissbrod and Bocken (2017) suggest that flawed idea generation processes may reduce organizations' ability to break the status quo. Bocken et al. (2017) report that workshops with diverse external stakeholders may be organized to generate and cluster radical ideas. Bocken et al. (2018) observe that experiments in the early phases of the innovation process require fewer resources than later on and can be conducted internally as opposed to in a real-life context. Furthermore, Bocken et al. (2011, 2013) propose tools to facilitate the generation of radical product and process ideas and sustainable value propositions. Brown et al. (2019) mention that a CE innovation process begins with the identification of a current system failure or a shared problem that helps stakeholders align visions and assess minimum viable capabilities for designing experiments.

There is, however, limited understanding about what kind of learning takes place in CE business experiments in the front end of innovation, which makes the management of such learning difficult. Learning from experiments in the front end phase is likely to be different from these later innovation process phases where the focus is on developing existing ideas into hypotheses and testing them (Bocken et al., 2018). Early on, experiments may focus on gaining an understanding of which ideas are worth pursuing and what specific needs are to be fulfilled.

## 2.4 Learning loops

To guide our investigation of learning from CE business experiments in the front end of innovation, we adopt the concept of *learning loops*, which have been related to experimentation but not specifically to business experiments. The idea of learning loops, first proposed by Argyris and Schön (1974), is useful for analysing whether learning is contained within well-established logics or if new logics and new solutions are being explored. The founders of the concept consider the detection and correction of error by individuals as the basis of organizational learning (Argyris & Schön, 1978). When it permits the organization to carry on its present policies or achieve its present objectives, the learning can be characterized as single loop. Higher-order learning, namely double and triple loop learning, occurs when an error is detected and corrected in ways that modify the organization's initial assumptions (Argyris & Schön, 1974; Argyris, 1976; Gugerell & Zuidema, 2017; Lozano, 2014; McKee, 1992).

*Single loop learning* is the simplest learning mode, where the results of an experiment are compared to the previous understanding of the topic to detect and correct errors in existing policies and practices and strengthen the participants' skills in the domain (Lozano, 2014). Existing norms and technological capabilities guide single loop learning that is associated with incremental innovation (McKee, 1992). It is the "general mode of action" where learning supports an organization's present policies and objectives (Argyris, 1978). In *double loop learning*, the participants' underlying assumptions are scrutinized to try to find the root causes of the problems at hand. Double loop learning relies on creative problem solving in which real-world situations are compared to future goals to identify the actions and changes needed to achieve them (Lozano, 2014). This kind of learning is associated with radical, revolutionary innovation as it allows organizations to see their capabilities and environment in new ways, revealing new opportunities (McKee, 1992). Finally, *triple loop learning* is highly reflective and aims to exploit the results of an experiment to build new processes and methodologies that could be used to address future problems (Lozano, 2014). Sometimes referred to as "meta-learning", triple-loop learning helps institutionalize innovation management within an organization and improve the outcomes of future innovation projects by learning from previous experiences, both successful and unsuccessful (McKee, 1992).

--------------------------------------Insert Figure 1 Approximately Here-------------------------------------

Figure 1. Learning from experiments in different phases of the innovation process (modified from Cooper (2013)).

# 3. Methodology

We set out to answer the research question: How to learn from CE business experiments in the front end of innovation? A single case study is an appropriate research approach to address our research question as it enables us to develop an in-depth understanding of the phenomenon in a real-life context (Yin, 2009) and the method is widely considered to be an appropriate strategy for exploring novel topics (Eisenhardt, 1989). A case study also enables us to generate managerially relevant knowledge due to the involvement of managers (Gibbert et al., 2008).

## 3.1 The selected case organization and the experiments

For the study, we searched for and selected an organization with a strong interest in developing a CE, and that has adopted experimentation as a new approach. The selected organization, here called ReCyc, is a publicly owned organization, which provides recycling and waste management services. A recent priority is to promote the transition towards a CE. ReCyc started the new practice of experimentation by conducting four distinct business experiments, (Experiments A-D), aiming to spur innovation in CE and recycling, upcycling in particular; i.e. aiming to produce higher-quality materials and improved functionality (Lüdeke-Freund et al., 2018). In the long run, these new solutions could create business opportunities for ReCyc itself, the partner organizations or totally new actors. The research team followed the preparation, implementation, and aftermath of the experiments and collected data from each of the four experiments, but did not have an active role in the development or roll-out of the experiments. The case company was anonymised for confidentiality reasons.

### 3.1.1 Experiment A: Brainstorming workshop on construction waste rejects

The purpose of the experiment was to find feasible applications for construction waste rejects. "Rejects" refers to construction waste that remains when other parts are reused or recycled, and are initially considered unsuitable for any use. The experiment included a half-day brainstorming workshop, facilitated by a consultant and run face-to-face with the participants, but also used digital tools for gathering and grouping application ideas. A diverse group of participants were invited to the workshop. They were chosen from ReCyc's existing networks and included people working in the construction and waste management industries. Some of them were technical experts on the topic, but not all. The workshop strengthened the participants' understanding of feasible application areas. Most of the ideas were already known; no breakthrough ideas were formed, but a couple of the ideas had some potential.

### 3.1.2 Experiment B: Market dialogue on waste incineration slag

The aim was to map and ideate potential applications for slag that is produced in waste incineration plants. It was hoped that the experiment would provide inputs for an upcoming competitive tendering for the treatment of waste incineration slag. The experiment started with a face-to-face workshop with representatives from companies that were interested in submitting a bid and various experts on the topic such as consultants and researchers. The idea was to engage in market dialogue where ReCyc and the suppliers would exchange knowledge about solutions so ReCyc could formulate a well-specified invitation to tender and receive better offers. The workshop was facilitated by an external service provider. After the workshop, there was an opportunity for the companies to continue discussions in private with a ReCyc representative. The conversation also continued on an online platform to which all participants were invited. In the end, no new applications were identified for the material, but the experiment helped ReCyc understand the topic in more depth. The experiment and its preparation also benefited the tendering, as more time and effort was invested in the process than usual.

### 3.1.3 Experiment C: Ecosystem workshop on waste incineration slag and ash

The experiment aimed to find new applications for waste incineration slag and ash, especially by envisaging radically novel solutions. The experiment comprised a full-day workshop, which was facilitated by an external consultant. The workshop was divided into two main parts. In the first part, the participants engaged in open ideation of new potential applications for slag and ash. The second part focused on building a shared future vision and understanding of the ecosystem that the participants comprise. Most of the participants were companies that had been involved in an earlier collaboration project. In addition, experts from a research centre were involved. Some of the ideas generated in the workshop were already known. They were, however, further developed by focusing on the network perspective and outlining the ecosystem that is needed to implement the ideas. New out-of-the-box ideas were also proposed and discussed, but their feasibility and potential were not considered very high.

### 3.1.4 Experiment D: Innovation camp for a circular economy centre

The aim of the experiment was to create and develop new innovative and feasible ideas for the organization of CE centres. A CE centre is a business park where multiple companies operating in a CE are located in the same place to achieve synergies. A hackathon-style innovation camp was organized with international and multidisciplinary teams of higher education students as participants. Four groups of three to six students were formed and each of them set out to develop solutions for a specific function of a CE centre. The groups were briefed on the topic and they had 24 hours to develop solutions after which they pitched them to a panel of experts. Their work was supported by innovation tools such as short guides to various design thinking methods. The innovation camp resulted in some improvements to existing CE centre plans and some ideas that were not considered feasible.

## 3.2 Data collection

To acquire a comprehensive understanding of the four experiments, various data sources were used, as synthesized in Table 1. The primary data collection method was semi-structured interviews. The research team, comprising two researchers, interviewed individuals within ReCyc, service providers that were used to facilitate the experiments, and other stakeholders such as external experts and companies that participated in the experiments. The interviewees were selected to form a comprehensive set of stakeholders with an active role in an experiment. The interviews were conducted after the experiments to be able to explore what has been learned from the experiments. The interviews were complemented with other data sources, such as feedback surveys, internal documents and presentations, data from digital platforms, and observation and informal discussions before the experiments. The interviews followed a general thematic guide that included the following topics: the interviewee's profile and role, description of the experiment and its methods, the experiment's goals, the composition of participants, stakeholders' incentives, and the links between the experiment and the organization's innovation process. The interviews were conducted in May-October 2018. The interviews were recorded and transcribed verbatim.

Table 1. Data collection

| Experiment | Data sources |
|---|---|
| Experiment A: Brainstorming workshop on construction waste rejects | 5 interviews: ReCyc (3), service provider (2), companies (2)<br>Participatory observation<br>Summary report<br>Discussion data from the online platform<br>Feedback questionnaire results |
| Experiment B: Market dialogue on waste incineration slag | 7 interviews: ReCyc (3), experts and consultants (3), company (1)<br>Discussion data from the online platform<br>Participatory observation<br>Presentations |
| Experiment C: Ecosystem workshop on waste incineration slag and ash | 3 interviews: ReCyc (1), workshop moderator (1), participant, recycling expert (1)<br>Participatory observation<br>Summary report |
| Experiment D: Innovation camp for a circular economy centre | 2 interviews: ReCyc (2)<br>Feedback report (feedback from participants)<br>Handbook for the innovation camp<br>Final report of the camp |

## 3.3. Data coding and analysis

The transcribed data was coded by two researchers using NVivo. The research followed an abductive process of inquiry, where empirical findings may reveal the need to redirect the existing theoretical model and theoretical insights may guide data collection and analysis (Dubois & Gadde, 2002). Overall, the coding and analysis process was iterative and included frequent face-to-face discussions where the emerging codes and findings were discussed and critically challenged until an "intersubjective consensus" was reached (Miles et al. 2014, p. 13).

The process started with getting to know the data, i.e. both researchers individually read all interview transcripts and additional data. This phase included initial coding (Saldaña, 2009), i.e. breaking down the data into parts, examining and comparing similarities and differences, as well as notes and analytic memos (Miles et al., 2014) related to connections between different observations and data sections. The different data sources presented in Table 1 were complementary in building a rich picture. Initial coding provided an inventory of topics and connections between them that guided us in the next steps. This process also triggered a literature search to identify a theory that could help explain the emerging insights (c.f. Dubois & Gadde, 2002), and the concept of learning loops (Argyris, 1976; Gugerell & Zuidema, 2017; Lozano, 2014; McKee, 1992) was considered fitting to advance the understanding of learning from experiments.

In the second cycle of coding, we focused on learning and CE innovation challenges. First, having adopted a learning perspective, we re-coded all the transcribed data from that viewpoint. This process resulted in 11 types of learning, which were further clustered according to the concepts of single, double and triple loop learning that were derived from theory. Here, we contrasted the emerging findings from the data with insights from the literature on learning loops. This abductive analytical strategy allowed us to revise and refine emerging data-driven observations with theory-driven insights and strengthen the theoretical relevance of the findings, as the findings were connected to the theory already in this phase of the research process (Dubois & Gadde, 2002). Next, we focused on the challenges of a CE innovation and used focused coding, i.e. categorizing coded data based on thematic similarity (Saldaña, 2009), to cluster the initial codes. As a result, we created six categories of CE innovation challenges, as presented in section 4.4 and Appendix.

We compared these identified challenges of CE innovation with the identified 11 types of learning and searched for connections that could help us understand how learning may promote CE innovation. This was done by drawing various mind maps and with help of data matrix, i.e. by arranging the vast array of material into an "at-a-glance" format, which enabled reflection, verification and conclusion drawing (Miles et al., 2014). We noticed that single and double loop learnings connections to the CE innovation challenges were modest, but found that several triple loop learnings can aid in answering these challenges. We contrasted and validated these findings by going iteratively back to the data, as also suggested by Miles et al. (2014).

The quality of the research was improved by involving both researchers in the data collection and analysis and using multiple data sources (Yin, 2009). The results were presented to the main contact persons at ReCyc to ensure the validity of the findings (Yin, 2009).

# 4. Results

In this section, we elaborate what kind of learning takes place in the experiments in the front of innovation and present 11 identified forms of learning, categorized according to the classification of single, double, and triple loop learning. Table 2 summarizes the main learning outcomes of the experiments. We further report how learning from the experiments is connected to CE innovation challenges.

Table 2. Main learning areas in the experiments

| **Learning loop** | **Experiment A** | **Experiment B** | **Experiment C** | **Experiment D** |
|---|---|---|---|---|
| Single loop | *Confirmation* of known solutions mainly related to earthworks, construction foundations, etc.<br>*Prioritization* of known solutions.<br>*Exclusion* of ideas that are known not to work. | *Confirmation* of a set of well-known traditional solutions.<br>*Development* of existing ideas by elaborating their implementation and requirements.<br>*Prioritization* of known solutions.<br>*Exclusion* of several proposed ideas. | *Confirmation* of ideas that were already known before the workshop.<br>*Development* of existing ideas and understanding of the ecosystem that is needed to implement them.<br>*Prioritization* of known solutions.<br>*Exclusion* of several proposed ideas. | *Confirmation* and *development* of existing ideas, most importantly of a circular economy showroom. |
| Double loop | No breakthroughs, *out-of-the-box ideas* with unknown feasibility | No breakthroughs, *out-of-the-box ideas* with unknown feasibility. A new idea was tested with no significant results. | No breakthroughs, some *out-of-the-box ideas* with unknown feasibility | No breakthroughs |
| Triple loop | Ambiguity in *challenge design* leads to lack of focus in ideation.<br>Difficulties in combining participants' perspectives.<br>IT-supported brainstorming *tools* suitable for open-ended ideation. | Competitive tension among participants hinders discussion.<br>Online platform is suitable for engaging and documenting in-depth discussions.<br>Difficulties in maintaining *participants' motivation* over time.<br>A facilitator is also required for online discussions. | Involving the "usual suspects" directs ideation to known sectors.<br>Ecosystem mapping is an effective tool for stimulating systemic thinking.<br>Value of having a facilitator with expertise in the subject. | Multi-disciplinarity balances creativity and feasibility.<br>Pre-reading material ensures that all participants have sufficient background knowledge.<br>Learning new ideation *tools* is time-consuming. |

## 4.1 Single loop learning

Four forms of single loop learning were found in the experiments: confirmation, development, prioritization, and exclusion. These are categorized as single loop learning because they increase understanding and skills related to existing policies and methods, but do not result in the questioning of fundamental assumptions. At the front end of innovation, single loop learning can be interpreted as the exploration of an existing opportunity space without challenging the underlying paradigms of what is possible and where to look for solutions (Bessant et al., 2014).

**Confirmation.** Confirmation of existing beliefs was the most prevalent form of single loop learning. Confirmation strengthens existing ideas and understanding; support for them comes from multiple sources and in different forms. According to the interviewees, most of the identified solutions were already known before the experiments. This is true for all four experiments. One apparent mode of learning was strengthening existing beliefs about the available solutions. A ReCyc representative summarized the outcome of Experiment A by saying, "It supported our earlier understanding that there are no new breakthroughs. The solutions that were discussed in the event were the traditional ones. I was left with the impression that the situation is similar both when it comes to processing the material and finding applications for it".

**Development**. The experiments also enabled the further *development* of previously known ideas: existing ideas were extended and re-evaluated, resulting in richer and more mature versions of them. Regarding Experiment C, a ReCyc representative said that the participants saw the experiment as an opportunity "to refine their idea further and promote it". In addition, the workshop strengthened the participants' knowledge of the interdependencies between organizations and the future vision of the field. In Experiment D, the participants were given lots of briefing material on the status quo of various CE centres and each team was assigned to work on a specific function, such as material processing or sorting. This can be seen as a way to guide the participants to develop further the rough ideas proposed by the organizers at ReCyc. In Experiment B, the online platform enabled in-depth discussions on the proposed ideas. Consequently, idea development could be continued after the single face-to-face event.

**Prioritization.** Prioritization is a form of single loop learning where existing ideas are compared with each other to understand their relative strengths. In Experiment A, and to a smaller extent in the other experiments as well, there was an element of *prioritization* involved. The proposed ideas were evaluated by the participants and the best ones were identified. The collective efforts induced learning about the relative value of alternative solutions.

**Exclusion**. Finally, learning was achieved by means of *exclusion*. Exclusion means rejecting proposed ideas and thus gaining a more comprehensive view of the opportunity space. By inviting experts to present their ideas, such as in Experiments A, B, and C, the organizers learned of ideas that did not match their current needs. Consequently, they acquired a well-informed view that there are no obvious solutions that they should be aware of. As an external expert involved in Experiment B pointed out, "Well, it is also a result that we have searched and didn't find anything very surprising".

## 4.2 Double loop learning

Three forms of double loop learning were identified: out-of-the-box ideas, mental model changes, and widespread change. Here, new perspectives are adopted and existing policies and methods are questioned. At the front end of innovation, double loop learning corresponds to the exploration of a new opportunity space (Bessant et al., 2014).

**Out-of-the-box ideas**. The organizers at ReCyc hoped that the participants would adopt new cognitive frames in their ideation and generate out-of-the-box ideas that do not rely on existing solutions and their underlying logics. The outcomes were, however, modest in this respect. According to an external expert in Experiment B, "The big goal was to find some genuinely novel applications for the material and apparently that won't be fulfilled". Similar results were observed in all experiments.

In contrast to the organizers' impressions, some of the interviewees reported highly novel ideas being proposed. These out-of-the-box solution proposals were considered unrealistic, however, as they were thought to have no business potential or practical feasibility. According to a critical view by a company representative in Experiment B, "Those who lack understanding and competencies present ideas that have already been tried ten times before".

**Mental model changes**. The interviews revealed a more indirect mechanism for double loop learning to occur. The experiments may have an indirect effect by triggering changes in participants' mental models, breaking the barriers of conventional thinking, and getting them to discard outdated beliefs. A company representative in Experiment A observed that "Perhaps the most important result of workshops like this is that we put effort into activating ourselves to think beyond what already exists".

**Widespread change.** Potential for more widespread change was also identified: the results of the experiments may reach wider audiences via interorganizational interactions. Widespread change includes knowledge transfer and mental model changes that reach actors beyond those who participated directly in the experiments. As an external expert in Case B noted, "These [participating] companies surely transmit the knowledge from the experiment to other customers of theirs. They can spread the message of what is possible and how and what kind of models can be used".

## 4.3 Triple loop learning

Triple loop learning was a significant learning category in the experiments. Triple loop learning is based on participants' reflection on the experiments and their results and generates insights on processes and methodologies for solving future challenges. The findings in this area reveal interesting insights into the elements in designing innovation experiments and guidelines on how to enhance their effectiveness. Four forms of triple loop learning were identified, each addressing a specific aspect of the processes and methodologies of organizing innovation experiments: designing the challenge, selection of participants, the motivation of participants, and tools and resources.

**Challenge design**. Each of the experiments aimed to solve a distinct innovation problem. These problems were formulated as challenges that the participants were invited to solve. Challenge design refers to the formulation of a question, such as "Can you propose some feasible applications for construction waste rejects?" in

Experiment A. Challenge design also included background materials and a briefing to inform the participants about the problem and give them some understanding of current knowledge on the issue.

Learning related to challenge design included the following key takeaways. First, highly technical challenges should be avoided if all the participants do not have sufficient technical competences. Second, open-ended challenges may generate ideas with low feasibility. It may be better to rule out some approaches to focus the ideation efforts on areas of high potential. Third, the organizers need to strike a balance between giving the participants too much and too little background information. On the one hand, too superficial a briefing may result in participants misunderstanding the innovation problem and proposing ideas that are already known. On the other hand, too extensive a briefing may exhaust the participants and guide them to a certain viewpoint, thus reducing out-of-the-box thinking. Fourth, concrete examples such as material samples could be used to make the problem more approachable and stimulate creativity. More extensive and detailed background reading material can also be given beforehand. Finally, the challenge should have direct connections to ongoing activities in the organization to ensure efficient follow-up and exploitation of the results.

**Selection of participants**. Selection of the participants for the experiments determines the available human capital for solving the chosen challenge. Learning how to choose the most suitable participants is, therefore, a critical part of running innovation experiments. The participants in Experiments A, B, and C were company representatives and experts, and Experiment D included higher education students. In the first three experiments, the participants were chosen from the organizer’s existing networks.

The experiences generated some thoughts on what to consider when selecting participants for future experiments. First, the interviewees suggested a trade-off between the breadth and depth of the participants’ expertise. Having (mostly) experts as participants stimulates more profound discussions and enables the evaluation of idea feasibility but limits the diversity of perspectives and the number of out-of-the-box ideas. Second, the industry background of the participants matters. The participants selected steer the search for new application areas toward their respective industries. For a truly open-ended search, participants with diverse backgrounds are needed. Third, inviting competitors to the same workshop may restrict discussion if the aim is to develop ideas with short to medium term business potential. Finally, language issues should be considered: a trade-off between getting the best international experts and ensuring fluent discussions in the participants’ first languages.

**Motivation of participants.** Participating in innovation experiments requires time and potentially generates other costs as well. Stakeholders are not likely to attend if they do not expect the benefits from attendance to exceed the investments. To ensure the attendance and contributions of the selected participants, the organizers need to understand how to motivate them. The study revealed the following insights about participant motivation. Professional interest and networking opportunities were found to form the core motivation for many company representatives. By linking the experiments to future purchasing needs, the organizers may be able to attract potential supplier companies. Monetary compensation may be considered for motivating external experts such as researchers and consultants that have rare competences and fresh perspectives. Collaboration with educational institutions may provide access to students that are motivated by education credits. In general, it was considered important to explicitly state expectations for each participant: why they were invited and how they are expected to contribute. Furthermore, using online tools may raise additional issues. It was a significant challenge to motivate the participants to check and contribute to online discussions on a regular basis after the initial event in Experiment B.

**Tools and resources.** The experiments varied in what kind of ideation and workshop tools and external (human) resources were used. In Experiments A and B, digital tools were used, whereas Experiments C and D had no significant digital elements. Experiment A adopted a hybrid approach that combined a face-to-face workshop with the use of computers in writing down ideas and arranging them. The software used was considered to increase the efficiency of the experiment: more ideas could be collected in the same amount of time and no additional effort was needed to document the workshop. Some critical views were expressed about how the use of computers decreased open discussions and the visualization of ideas by drawing. This would suggest that there may be a trade-off between the number of ideas (efficiency) and their innovativeness (effectiveness) and that the digital tool shifted the balance towards the former. Experiment B started with a face-to-face workshop and continued on a digital platform for a couple of months. The platform allowed in-depth discussions, as it was possible to contribute more lengthy arguments and materials. The documentation of the discussions was also automatic.

Other tools used included the bread and butter of ideation workshops: flip charts and Post-it notes. Beyond these, in Experiment D the participants were given instructions and materials to conduct various problem-solving and design exercises, such as SWOT, the five whys, personas, and storyboards. Their use was limited, however, due to time constraints that restricted the teams' ability to explore new methodologies.

All experiments had external facilitators: consultants in Experiments A, B, and C and educators in Experiment D. There was a wide consensus that a facilitator has a key role in a successful experiment. In two of the experiments (B and C) the facilitators were also experts in CE, which the interviewees considered helpful in guiding the discussions in fruitful directions.

## 4.4 Overcoming CE innovation challenges

By examining the relationships between the different forms of learning and CE innovation challenges, we determined which type of learning was best suited to overcoming these challenges (see Appendix for details of CE innovation challenges), as presented next. The connections were modest for single and double loop learning. Incremental ideas from single loop learning were associated with already known challenges and no major advances in overcoming them were observed. Radical ideas from double loop learning aimed to solve some specific challenges, typically by proposing novel technological solutions or methods for wider engagement of the ecosystem. Their feasibility was low, however.

The most significant contributions to overcoming CE innovation challenges originated in triple loop learning (Figure 2). Hence, triple loop learning may promote CE innovation by enabling the organization to adjust its experimentation methods and increase its ability to create conditions conducive to double loop learning in the future. These findings reveal interesting guidelines on how to enhance the effectiveness of innovation experiments.

------------------Insert Figure 2 about here---------------------

Figure 2. Main challenges of CE innovation and triple loop learnings from the experiments.

The first CE innovation challenge relates to *ecosystem level change*. Our results emphasize both the importance and the challenge of involving all value chain actors in innovation activities and that of cross-sectoral collaboration. The value chains are long, and the owner of the waste is often located far from the potential end-user. Moreover, the owner of the waste does not always have an incentive to search for novel solutions for upcycling, as they can simply "dump" the waste. Our results reveal some insights about how these challenges can be considered in designing innovation experiments. *When selecting participants,* it is important to engage a diversified group of participants representing different stakeholders and different sectors. By conducting these experiments, ReCyc was able to engage a diversified group of stakeholders and to signal to the wider group of stakeholders that the organization is looking for new solutions. Also, it seemed to be important that participants *understand their role* in the wider ecosystem. When *considering tools* for the experiment, it is important to ensure the interaction between different stakeholder groups.

Second, *the timespan of the innovation process* is often long and getting returns on the investment is expected to take a long time, which contradicts the companies' search for short-term profit, making the commitment to CE innovation processes difficult. The long timespan also makes the responsibilities in the ecosystem unclear. To overcome these challenges, it is important to consider *challenge design,* and to include a long term perspective, for instance by presenting industry trends.

The third challenge of CE innovation relates to *organizational inertia.* The interviewees argued that CE innovation requires ambitious goals and a comprehensive understanding of demand drivers. From a company perspective, the various drivers for innovation (e.g. environmental and economic) are often in conflict, and economic drivers are favoured over the others in decision-making. Out-of-the-box thinking is important in the search for new ideas, but the interviewees perceived this as difficult due to the recycling industry being traditional and old fashioned. To overcome these challenges it is important *to include participants* that are not mired in existing constraints and mindsets and *to use tools and facilitators* that can help with out-of-the-box thinking.

The next challenge relates to the *lack of market demand.* The challenge is that instead of market demand the main driver for innovation is the existence of waste or leftover material. Virgin raw materials are, however, still relatively cheap and often considered better and safer than recycled material. Finding end-applications for the waste is a difficult but essential part of the innovation process. The respondents also saw that they need to search for potential end-applications outside traditional fields. However, the actors might not be willing to move into new fields. The triple loop learnings provide insights on how to overcome these challenges. First, *when selecting participants*, it is important to include customers as well as a diversified group of participants representing different stakeholders and different sectors, as this would aid in identifying potential end-applications outside the traditional ones. *Challenge design* seems to play an important role, and one should avoid formulating an overly open-ended challenge so that participants must come up with concrete ideas. Including background material about the markets might also help. Separating ideation and the evaluation of idea potential into different phases, as in experiment A, may also be useful.

The last challenge relates to the *technological complexity of CE innovations*. The interviewees emphasized the technological difficulty of new recycling solutions and different kinds of risk and safety aspects. The material risks are high as the waste material is often poorly known and heterogeneous. It is difficult to find potential applications where the recycled material would have better qualities than the virgin material it would be replacing. To overcome these challenges it is important in *challenge design* to match the technological difficulty level with the participants' level of expertise. Including a briefing about the latest research might help participants to understand the technological restrictions and possibilities. When *selecting participants,* it is important to involve top experts from various fields. When *selecting tools*, consider having a tool that facilitates in-depth discussion.

# 5. Discussion

## 5.1 Theoretical contributions

This study has two main theoretical contributions. First, our findings outline how learning from experiments in the front end of innovation may help develop ideas and concepts that can advance a CE (Figure 3). According to the experiences of ReCyc, single loop learning focused on refining existing solutions was considered to have limited outcomes, as existing solutions are unable to address the CE innovation challenges that prevent organizations from implementing CE principles (cf. Tura et al., 2019). To develop CE innovations, these challenges must be acknowledged in the front end phase so that feasible ideas and concepts may be generated. Double loop learning that goes beyond existing solutions is needed. Generating suitable radical ideas may, however, be difficult if the experiments are not designed to take CE innovation challenges into account. We propose that, in such situations, focusing on triple loop learning may be the answer. When exposed to deep reflection, experiments may lead to insights on how the experimentation process should be developed (Lozano, 2014) to overcome the barriers to CE innovation. Triple loop learning may help organizations enhance their radical innovation capability by helping them choose suitable experiment designs and hence facilitating the exploration of a new opportunity space in the front end phase (Bocken et al., 2018).

Second, this study elaborates the concept of learning loops – single, double and triple loop learning – (Argyris, 1976; Argyris & Schon 1974; 1978; Gugerell and Zuidema, 2017; Lozano, 2014; McKee, 1992) in the context of front end of CE innovation. We identify 11 forms of learning from experiments and conceptualize that, in this context, the difference between single and double loop learning may be understood through the idea of opportunity spaces: available domains in which potential ideas are searched for and selected (Bessant et al., 2014). Existing spaces are defined by incumbent business models, product architectures and value networks within which a local search for new opportunities takes place via incremental learning forms such as confirmation, development, prioritization and exclusion. For radical ideas, the exploration needs to go beyond the existing frames, which introduces significant uncertainty (Bessant et al., 2014). Here double loop learning may produce out-of-the-box ideas, mental model changes and widespread change in the industry, and lead to radical innovations (McKee, 1992). The organizational learning literature suggests that the transition from single to double loop learning is difficult due to peer and supervisor pressure, risk avoidance and bureaucracy that generate organizational inertia (e.g. Argyris, 1976; McKee, 1992). Our findings highlight that before such organizational issues become relevant, managers need to ensure that the experiments yield relevant outcomes. We propose that triple loop learning may fuel a gradual transition to double loop learning. At the core of triple loop learning is the exploration of the experimentation activities themselves, leading to insights on how efficient and effective experiments should be conducted in terms of challenge design, participant selection and motivation, and tools and resources to enhance the capability to achieve double loop learning.

----------------INSERT FIGURE 3 APPROXIMATELY HERE----------------------

Figure 3. Synthesis of the results.

## 5.2 Practical implications

Beyond its theoretical contributions, this study has some important *practical implications for managers* who wish to make the transition towards a CE. Knowledge of the 11 forms of learning may be used to design business experiments that address specific needs and to facilitate structured reflection after the experiments. Particularly for managers with limited experience in conducting business experimentation, it is important to understand that while experimenting with difficult CE problems may not immediately generate radical solutions it may be valuable in developing experimentation and innovation capabilities. The importance of experimentation capabilities is also emphasized by Weissbrod and Bocken (2017), who point to fast learning through project experiments. In line with previous studies (Weissbrod & Bocken, 2017; Bocken et al., 2018), our results support the learning-by-doing approach in developing such competences.

Our results related to triple loop learning suggest practical guidelines for managers planning circular economy business experiments at the front end of innovation. Figure 4 illustrates how managers may attempt to overcome identified CE innovation challenges by paying attention to specific aspects in designing experiments.

For example, to promote systemic change, experiments should promote interactions among a diversified group of participants and include a reflection of each participant's role in the wider ecosystem.

On a more general level, it appears that the organizers should choose whether to emphasize the breadth or depth of the potential contributions. For a focus on breadth, one should propose an open-ended challenge, attract a diverse group of participants with multiple perspectives, and use methods that facilitate the efficient input and documentation of all ideas. In contrast, a focus on depth would require a more specific challenge, experts in a particular technology and/or industry, and methods for more lengthy discussions and evaluation of ideas. Mixing these two foci may create tensions, as the participants may experience conflicting goals and feel unable to use their expertise to its full capacity, and it may be beneficial to conduct separate experiments for i) open ideation and ii) idea assessment and development.

----------------INSERT FIGURE 4 APPROXIMATELY HERE----------------------

Figure 4 Business experimentation design elements to overcome CE innovation challenges.

### 5.3 Limitations and future research

Our study has several limitations that point to opportunities for future research. First, we investigate a specific CE context – recycling, which has special characteristics, e.g. it requires particular knowledge in several areas such as material sciences and the ability to deal with the particular physical and chemical properties of a large variety of materials. Further, the business is often driven by the availability of waste material, instead of identified market demand. As for future research, other CE contexts could provide a more varied view of learning from business experiments at the front end of innovation. The experiments we studied were the first four conducted by the case organization. While they revealed various learning outcomes, future research could investigate organizations with more experience, as it is likely that they would produce different learnings and provide new insights about how the experiments should be implemented and what can be learned from them. While focusing on a specific innovation process phase may produce in-depth insights, we also encourage future studies to adopt a longitudinal perspective to deliberate learning and follow how different experiments are used in succession from ideation to hypothesis testing to large-scale pilots. Particularly interesting is how to transfer and integrate the learnings from experiments in the front end to the mainstream organization and the value chain. Our study touched upon topics that we did not investigate more deeply, such as using intermediaries in locating participants, crowdsourcing ideas from a larger number of contributors, and the applicability of various ideation methods (e.g. design thinking methodologies) in stimulating ideation. The applicability of these innovation management approaches to various CE contexts merits further attention.

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Appendix: CE innovation challenges

| CE innovation challenge category | Details |
|---|---|
| **Ecosystem** | ● Systemic approach is needed *(All experiments).*<br>● The owner of the waste is often far away from the end-user (*Experiments A, B and C).*<br>● The owner does not always have an incentive to search for novel solutions for upcycling, as they can simply "dump" the waste *(Experiment A and B).*<br>● Difficult to find an organization that would actively drive the development of an innovation *(All experiments).*<br>● The engagement of the whole value chain is needed *(All experiments).*<br>● Cross-sectoral collaboration and new actors are needed *(All experiments).*<br>● A common motivation or goal shared by the different actors is needed *(All experiments).* |
| **The timespan of the innovation process** | ● The timespan of the innovation process is often long (*Experiments A, B and C).*<br>● Getting returns on the investment is expected to take a long time (*Experiments A, B and C).*<br>● The long timespan of the innovation process conflicts with the companies' search for short-term profit (*Experiments A, B and C).*<br>● The long timespan makes the responsibilities in the ecosystem unclear (*Experiments A, B and C).* |
| **Technological characteristics** | ● The needed solutions are often technologically complex (*Experiments A, B and C).*<br>● The innovative CE solutions are subject to different kinds of risks: safety risks and material risks, as the waste material is often poorly known and not of uniform quality. The long-term effects of new solutions are difficult to assess, and solutions might have totally unexpected consequences. (Experiments A, B and C).<br>● Involvement of experts from various fields in the innovation process is required (Experiments A, B and C).<br>● Totally new approaches are needed: existing technologies not sufficient (Experiments A, B and C).<br>● Recovery of materials from products that are based on secondary raw materials needs to be taken into consideration (Experiments C).<br>● Recycled material should have better qualities than the virgin material it would be replacing. This is often difficult (Experiments A, B and C). |
| **Market** | ● Currently no real market demand for most proposed solutions (*Experiments A, B and C).*<br>● It is challenging to develop good value propositions as ideation starts with excess material or waste, not existing market demand (*Experiments A, B and C).*<br>● Finding applications for the recycled material is challenging (*Experiments A, B and C).*<br>● The volumes of waste and the market for the recycled material need to be on the same scale (*Experiments A, B and C).* |
| **Organizational** | ● The profit margins of new businesses are often low (*Experiments A, B and C).*<br>● Risk-averse companies (*Experiments A, B and C).*<br>● The environmental and economic drivers are often in conflict *(All experiments).*<br>● Comprehensive understanding of various demand drivers needed *(All experiments).*<br>● Ability to do out-of-the-box thinking is required *(All experiments).*<br>● Organizations should have ambitious goals *(All experiments).* |
| **Regulatory** | ● Current regulation related to the solutions is unclear (*Experiments A, B and C).*<br>● Regulation may change during the lifecycle of a recycled product (*Experiments A, B and C).* |

Figure 1. Learning from experiments in different phases of the innovation process (modified from Cooper (2013)).

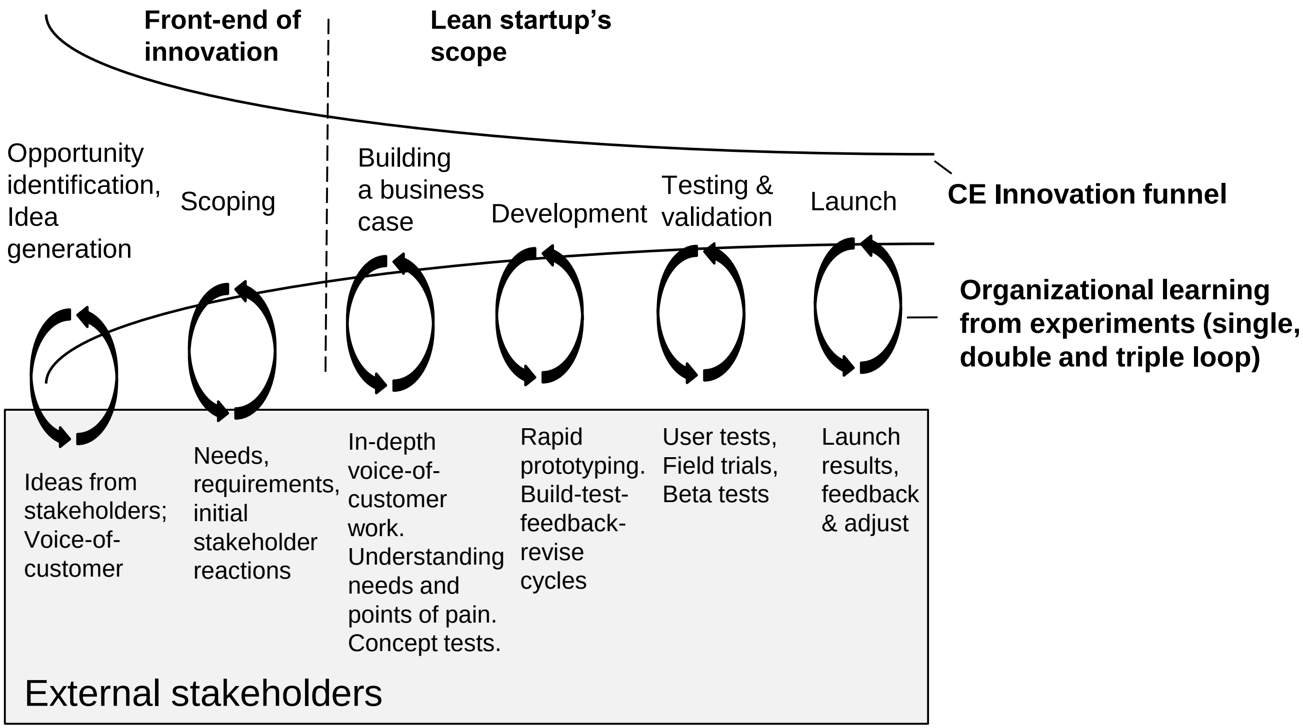

Figure 2. Main challenges of CE innovation and triple loop learnings from the experiments.

| CE innovation challenges | Triple loop learnings to overcome the CE challenges |
|---|---|
| **Ecosystem level change:**<br>Systemic change required.<br>The owner of the waste is often far from the end-users<br>Difficult to find a driver organization for innovation.<br>*Requirements*<br>• Engagement of the whole value chain<br>• Motivation and goal shared by involved actors<br>• Cross-sectoral collaboration and new actors | **Selection of participants:**<br>• Engage a diversified group of participants representing different stakeholders and sectors<br>**Motivation of participants**<br>• Make sure that participants understand their role in the wider ecosystem<br>**Tools and resources**<br>• Ensure interactions between different stakeholder groups to promote systemic thinking |
| **Long timespan**<br>Timespan of innovation process is often long.<br>Getting returns on the investment is expected to take a long time, which conflicts with the search for short term profit.<br>Long timespan makes the responsibilities unclear. | **Challenge design**<br>• Multiple experiments<br>• Include a long term perspective, for instance, start the experiment by presenting (mega) trends |
| **Organizational inertia**<br>Companies are risk-averse and stuck in their current business.<br>Conflict between environmental and economic drivers for innovation<br>*Requirements*<br>• Out of the box thinking and ambitious goals<br>• Understanding of various demand drivers | **Selection of participants**<br>• Include participants that are not mired in existing constraints and mindsets.<br>**Tools and resources**<br>• Use tools that helps in out-of-the-box thinking. |
| **Lack of market demand**<br>No real market demand for innovations.<br>Ideation is based on material, not on market demand.<br>Finding end-applications for the recycled material is challenging.<br>Volumes of waste and market for recycled material need to be on the same scale. | **Selection of participants**<br>• Form a diversified group of participants representing different stakeholders and sectors to identify new end-application<br>• Include potential customers<br>**Challenge design**<br>• Avoid too open-ended challenges, so that the participants have to propose concrete ideas.<br>• Include background material<br>**Tools and resources**<br>• Two-part experiments that separate ideation and evaluation of their potential. |
| **Technological**<br>Solutions are often technologically complex.<br>Innovations are subject to risks, such as safety risks and material risks.<br>*Requirements*<br>• In-depth knowledge from various fields<br>• Novel approaches<br>• Recovery of materials from products that are based on secondary raw materials<br>• Recycled material should have better qualities than the virgin material it would be replacing | **Challenge design**<br>• Match the technological difficulty level with the participants' level of expertise.<br>• Include briefing about latest research.<br>**Selection of participants**<br>• Involve top experts from various fields<br>• Involving experts from abroad might cause language issues if the discussion is not in the participants' first language.<br>**Tools and resources**<br>• Use tools that enable in-depth discussion |

Figure 3. Synthesis of the results.

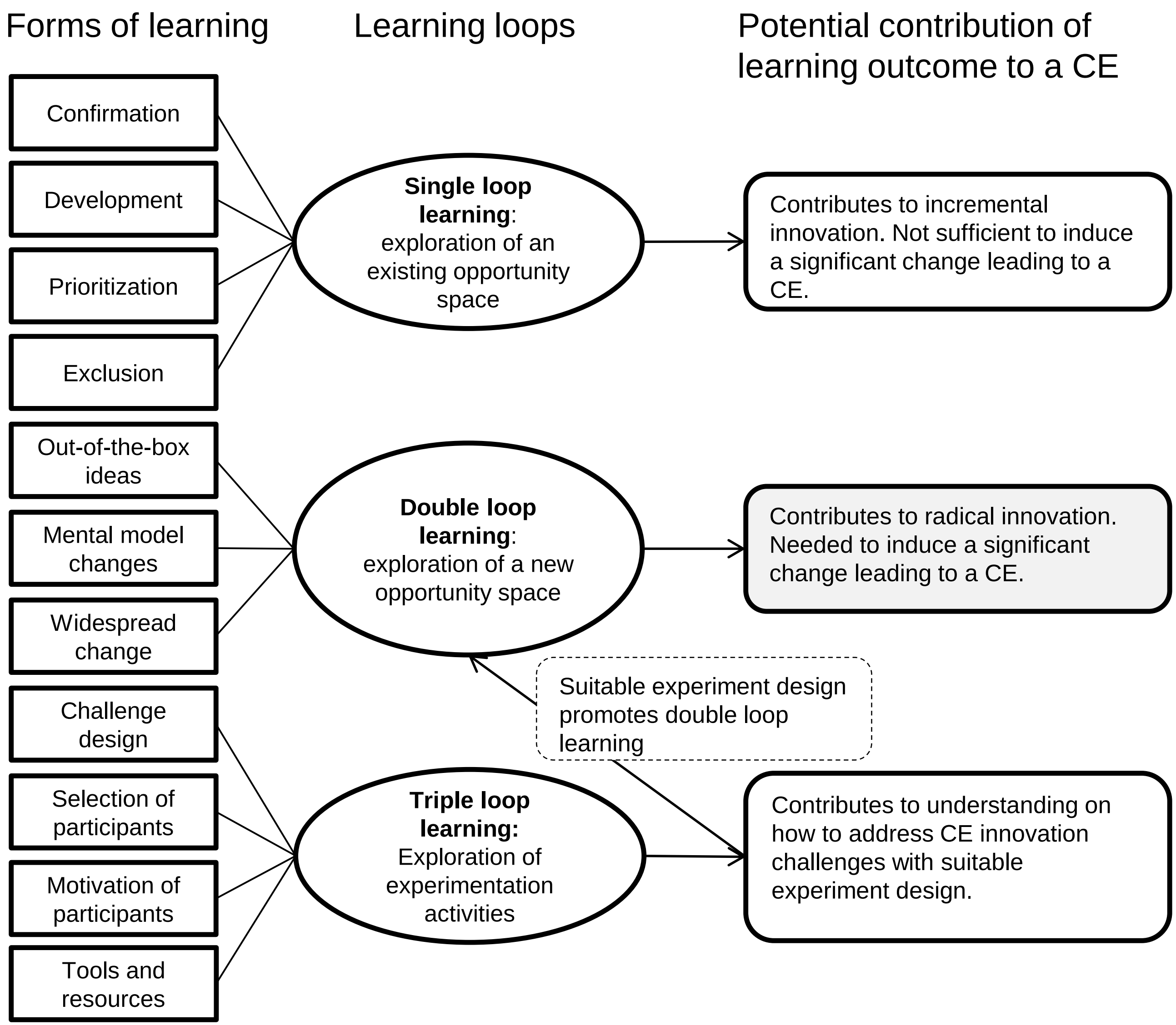

Figure 4. Business experimentation design elements to overcome CE innovation challenges.