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Perspective

Effective Communication of Underlying Research Philosophies Can Improve Circular Economy Research in the Foundation Industries

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Abstract
The drive to address environmental challenges in the Foundation Industries is leading to an ever greater, and more diverse, volume of Circular Economy related research. Despite increased expectations for research to achieve positive impact, authors do not always have the tools to effectively communicate to readers what their study's underlying research philosophy is, regarding how knowledge will lead to impact. We propose terminology for authors to concisely communicate their approaches to knowledge generation (fundamental or applied) and route to impact (reformative or transformative). Reformative research does not seek to fundamentally disrupt or change the prevailing (or conventional) production systems, whereas transformative research does. We provide recommendations for how authors can effectively communicate their study's research philosophy in an appropriate level of detail.

Keywords: Foundation Industries · Circular Economy · Glass · Metals · Cement · Ceramics · Chemicals · Paper

1. INTRODUCTION
The energy-, resource- and waste-intensive nature of the foundation industries (glass; metals; cement; ceramics; chemicals; paper (UKRI, 2021)) offers a prime case of the need for Circular Economy oriented research. The foundation industries operate on a large scale – estimates for annual global production are: 4.10 $Gtyr^{-1}$ of cement (USGS, 2024), >2.2 $Gtyr^{-1}$ of ceramics (Olsson et al., 2025), 1.89 $Gtyr^{-1}$ of steel (World Steel Association, 2024), 0.82 $Gtyr^{-1}$ of chemical products (Levi & Cullen, 2018), 0.40 $Gtyr^{-1}$ of paper (FAO, 2024), and 0.15 $Gtyr^{-1}$ of glass (Westbroek et al., 2021). In the UK, the foundation industries produce 28 Mt/yr of materials (corresponding to 75% of all materials in the economy); they also account for ≥10% of national CO_2 emissions and generate significant amounts of waste generation (>80 Mt/yr from mineral waste alone). As the range of research methods, technologies and possible interventions grows, as well as the breadth of environmental and social issues in focus, the possible routes to increasing circularity in the foundational industries multiplies, along with the routes to achieving positive change in general. Against this evolving backdrop, the intended route to impact of a given research article is not necessarily intuitive; especially for readers unfamiliar with the nuances of individual sectors. At the same time, there are often strong opinions amongst sector specialists around the relative effectiveness of suggested approaches e.g. (Scrivener et al., 2023). We propose that authors can effectively describe the underlying philosophy of their research to the intended audience through two components of their research output: the approach to knowledge generation, and the route for how that knowledge can then lead to impact (Figure 1). We describe how existing terminology for both these components could be used by authors, so that readers are better equipped to interpret and use that research – particularly for Circular Economy oriented research.

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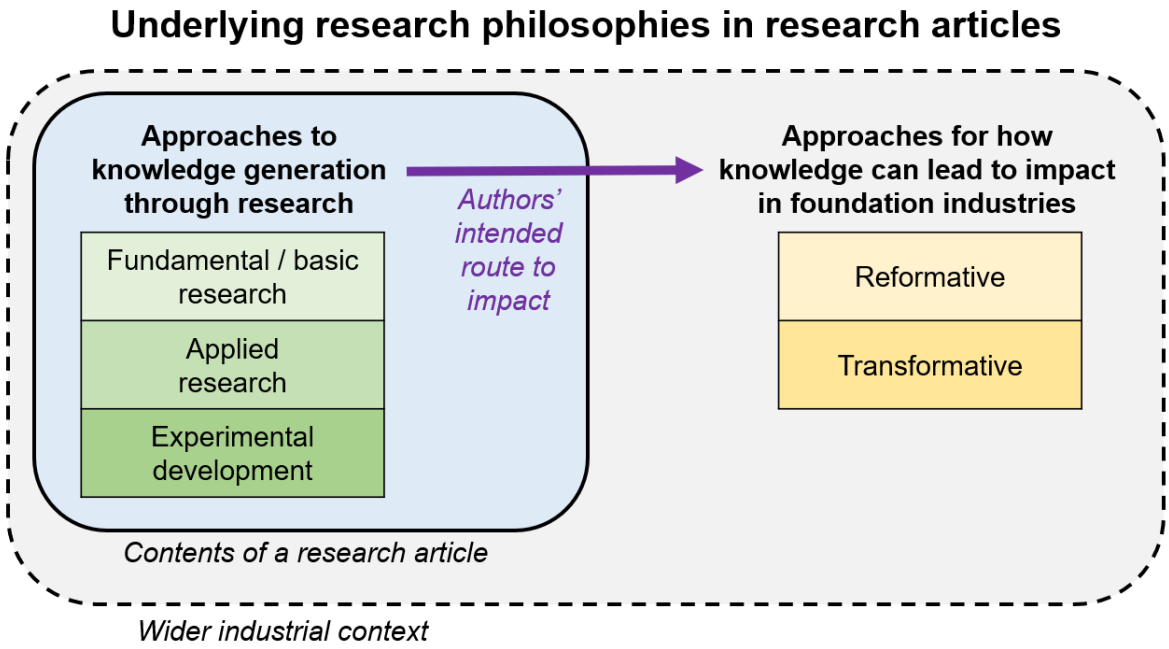

Figure 1. Research articles contain new knowledge, which can be generated through different approaches (i.e. Fundamental/Basic research, applied research and experimental development). In the wider industrial context, the knowledge contained in research articles can then be used to achieve impacts through different approaches (i.e. Reformative, transformative). Clear communication of authors' intentions about how they intend the knowledge generated could lead to impact, can ultimately lead to more effective application of that knowledge in the wider industrial context

2. APPROACH TO KNOWLEDGE GENERATION

For approach to knowledge generation, widely-used definitions are presented below (OECD, 2015, p. 45); an illustrative example is given for each, relevant to the Foundation Industries:

- **Fundamental/basic research** = "*experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts…*"[1]. E.g. Research seeking to develop our fundamental understanding of the glass transition phenomenon.
- **Applied research** = "*original investigation undertaken in order to acquire new knowledge… directed primarily towards a specific, practical aim or objective*". E.g. Research to understand levels of leaching of heavy metals if industrial waste is partly used in cement manufacture.
- **Experimental development** = "*systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes*". E.g. Research and practical work to develop diffusive heat capture devices in the ceramics sector.

3. ROUTE TO IMPACT

For intended route to impact, we believe it is essential for authors to describe *how* they intend the knowledge generated would improve circularity, or more broadly lead to positive impact, in a given foundation industry(ies). Specifically, the extent to which the innovation would radically disrupt majority (or conventional) production systems in a given sector. Alignment with, or disruption to, conventional production processes is an influential factor in determining the feasibility (including implementation timescale) for foundation industries, given their commonly shared characteristics (i.e. large-scale overall production; high CAPEX costs; restrictive sets of standards and/or customer expectations for products) (Hammond, 2022). "Reformist" and "Transformationist" terminology

[1]The last part of the definition given in the Frascati Manual "*…without any particular application or use in view*" is redacted here, because our focus on the Foundation Industries pre-defines a likely application or use.

is already used in Circular Economy research to distinguish different routes to change in industrial practice (Reike et al., 2018); we adapt these into simple terminology to distinguish different routes to impact, and provide an illustrative example for each:

- **Reformative research** = research whose path to impact does not fundamentally disrupt the majority (or conventional) production systems for a given application. E.g. Research that applies Artificial intelligence tools to improve the quality control of glassmaking.
- **Transformative research** = research whose path to impact sits outside of, or disrupts, the majority (or conventional) production systems for a given application. E.g. Research that aims at the bio-production of value added chemicals.

4. RECOMMENDATIONS

These simple descriptions could be especially useful for readers who are not researchers; e.g. policymakers, for whom clear descriptions around the impact of technological innovations is essential to generate evidence-based policy (Dosso et al., 2018). However, describing routes to impact as either reformative or transformative makes no claim about the potential magnitude of impact, and one route is not claimed to be superior to the other.

The use of such simple terminology (aided with sector-specific details) would clearly communicate a research article's underlying philosophy and thus help authors to focus their thinking, and readers to understand authors' thinking. An imaginary example combining both components might be: This study adopts an applied research approach to developing artificial intelligence tools for glass manufacturing, which can reduce material wastage by improving quality control; these findings can help achieve reformative impact in the glass sector, as these tools are straightforward to integrate into existing quality control systems.

Clearly describing the underlying research philosophy of a research study is something that many authors already successfully do – typically described in the Introduction section, with critical reflections in the Discussion or Conclusions. The terminology and approach presented here is not the only way to do this; these terminologies are also not intended to be 'watertight' definitions applicable to 100% of research (in some cases, studies could be categorized under more than one category). Instead, they are intended to be simple, intuitive and practical, and applicable to the majority of studies in the foundation industries. They are also intended to compliment other ways to describe the intended impacts of Circular Economy oriented research, e.g. slowing, narrowing and closing resource flows (Bocken et al., 2016). Crucially, authors describing their intended route to impact from a piece of research does not restrict its use solely within the author's intention. With so much research published and so little time available (both to read, and to implement industrial change), simple ways that can help research be easier to interpret can have a positive effect.

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AUTHOR CONTRIBUTIONS

Alastair T.M. Marsh: Conceptualization; Writing - Original Draft; Funding acquisition
Hisham Hafez: Conceptualization; Writing - Review & Editing

DECLARATIONS

Competing interests The authors declare no competing interests.

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